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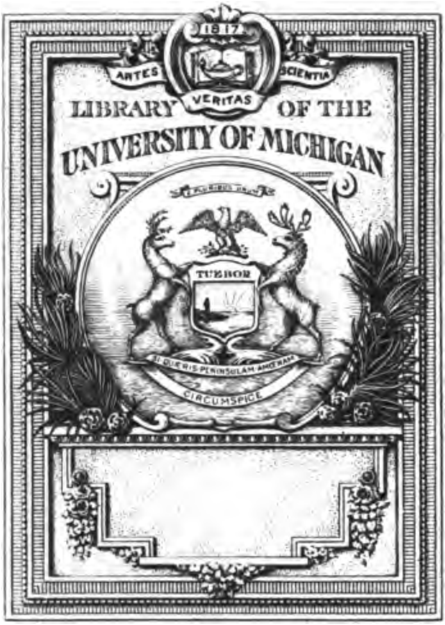

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AN ESSAY

On the Inveſtigation of the

Firſt Principles of Nature:

Together with the

Application thereof to ſolve the Phænomena

OF THE

PHYSICAL SYSTEM.

PART I.

CONTAINING

A New Philoſophical Theory

WHEREBY

Firſt Principles, with their Material Subſtances and Eſſences are traced and exhibited; the Limits of Inertneſs aſſigned; the Cauſes of Elaſticity and Tranſparency diſcovered; the real Mode of Light's Propagation determined; and various other Phænomena clearly explained. The Whole ſcientifically inveſtigated and demonſtrated

By FELIX O'GALLAGHER.

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DEDICATION.

To the KING.

SIR,

THE homage paid by Sciences is a tribute worthy of Kings, and which Kings alone are worthy to receive. The firſt characters in hiſtory have derived a great ſhare of their glory from their generous protection of Literary

1-17-40

Merit: and if there be a nation recorded by fame as illuſtrious or great, it is that where Arts were encouraged, and Sciences cultivated. Permit me, then, to inſcribe to Your Majeſty an improvement in the moſt noble of Sciences, —the Science of Nature.

If this Eſſay were capable of enhancing your renown, it would be due to your virtues, and joyfully dedicated to Your fame, by a loyal and affectionate Subject.

But though your greatneſs render You independent of the ſuffrage of Literature, Literature is not independent of You. The moſt valuable productions often ſtand in need of acceſſary embelliſhments: let this Work then, receive from Your Majeſty's Name, thoſe advantages of which it would be deprived by the obſcurity of its Author.

The ſublimity of Natural Philoſophy is ſuited to the dignity of a King, and its tendency to the benefit of Mankind is a recommendation, which enſures it the Patronage of Royalty. But if ever this uſeful Science could approach the Throne with confidence of protection, it is when adorned by a Prince, Whoſe extenſive views omit no object conducive to the advantage of his people, and Whoſe ambition is, rather to diffuſe happineſs at home, than to ſpread devaſtation abroad.

I am,

with all Fidelity and Devotion,

Your Majeſty's moſt Dutiful,

And Obedient Subject,

And Servant,

FELIX O'GALLAGHER.

PREFACE.

NOTHING is more deſireable than the inveſtigation of firſt principles, and a diſcovery of the material cauſes which actuate nature: and nothing would more conduce to ſuch a diſcovery, than to reduce natural philoſophy to the form of a ſcience, that is, to eſtabliſh therein certain incontestible principles as a ground-work for ſubſequent ratiocination, and to lay down a method for extending the ſcience by unerring rules adapted to the nature of the object propoſed, and adequate to its attainment. This ſcientific form was long wanted to mathematics, that pattern of Sciences, which were at firſt rather an aſſemblage of detached truths, diſcovered by different perſons, and independent of each other, than a train of propoſitions ſucceſſively emerging from each other, and all primarily founded on the ſame univerſal and ſelf-evident axioms. Thus, Thales the Mileſian diſcovered thoſe propoſitions which are now the 5th, 15th, and 26th of the Firſt, and alſo the 2d, 3d, 4th and 5th of the Fourth Book of Euclid: Pythagoras found out the 32d, 44th, 47th and 48th of the Firſt Book. To Oenopides are aſcribed the 12th and 13th, l. 1. But happily for the improvement of mathematics, Euclid collected the diſcoveries of theſe and other geometricians intoone connected ſyſtem, premiſing thoſe univerſal truths aſſumed as evident by all, thence deducing the more ſimple, and afterwards, by means of thoſe, the more complex propoſitions, and rejecting whatever was hypothetic or inconſiſtent. No ſooner had geometry been thus formed into a ſcience, than it began to receive the moſt extenſive and noble improvements: witneſs the ſublime Theorems of Archimedes, the Conics of Apollonius, the Subtenſes of Hypparchus, and the Spherics of Theodoſius. But the inconteſtible certainty of mathematical knowledge, which admits of neither doubt nor diſagreement throughout the whole learned world, and the facility wherewith the inventions of ages in this ſcience become now the acquiſitions of a few months are undeniable proofs of the unparalleled utility of a truly ſcientific form in any branch of literature. The neceſſity of a ſcientific method in the ſtudy of phyſics is ſtill more apparent. For certainly natural philoſophy or the ſtudy of the powers of nature muſt have preceded amongſt men, that of magnitude and dimenſions, as having a more immediate and general connection with all the neceſſities and conveniencies of life, and being the ſource of Agriculture, Botany, Medicine, &c. which from their neceſſity and utility are known to have been (and naturally ſhould be) the firſt of all arts and ſciences. Hence, from the earlieſt Greek philoſophers, of whoſe labours we have any monuments left, from Democritus, Thales, and Plato, down to the preſent times, experiments have been uſed to obtain a knowledge of nature. This has been the employment of the chymiſts of all ages, and at preſent engroſſes the attention of all philoſophers. Yet how far is natural philoſophy ſtill from the certainty, ſimplicity, and ſtability, which characterize mathematics. Various ſyſtems prevail in different countries; philoſophers of the ſame nation do not agree amongſt themſelves; the phænomena of the ſame experiments are variouſly interpreted; the ſame effects are aſcribed to different cauſes; and all our knowledge conſiſts of ſome diſtinct aſſemblages of propoſitions collected by the moſt able ſtudents in different branches of phyſics, from the ſame phænomena indeed, but on different principles of ratiocination. From all which it is clear that phyſics have ſcarcely, to this day, attained that degree of perfection, in which geometry was found by Euclid, when he digeſted it into ſcientific order. This chiefly proceeds from the want of a Baſis for philoſophizing like the axioms of geometry, or real natural ſtandards admitted by all, as grounds of ratiocination and fixed criterions to determine the interpretation of experiments. As an attempt to ſupply this defect, we have ſet out from the moſt inconteſtible of all principles, to wit, the exiſtence of a *Supreme Power* and *Wiſdom*, and have thence derived axioms equally undeniable. Theſe again lead to propoſitions, not ſo immediately evident, but demonſtratively true, and adapted (I conceive) to promote and attain the object of natural philoſophy, which is the knowledge of the *real eſſence* or *eſſences* of bodies, and of the acting principles of nature. Theſe axioms and propoſitions are not, indeed, cited and ſpecified in ſubſequent reaſonings with the preciſion and minuteneſs practiſed in mathematics; for that would render the ſubject dry, and interrupt a natural flow; but whoſoever will attend to the reaſonings made uſe of in the courſe of this work, will find them grounded on, and derived from the principles laid down in the Firſt Lecture; ſo that the remaining part (not to ſpeak of other advantages of which the learned readers will themſelves judge,) ſerves as a full illuſtration of the application of this phyſical theory.

To make the reader further acquainted with the method purſued in this work, we muſt make an obſervation on experimental philoſophy. By this name we are not to underſtand the obſervation and compariſon of thoſe phænomena alone, which require a mechanical apparatus to excite, or artificial means to diſcover. If ſuch phænomena were the only ſource of information, our knowledge of nature, however it might deſerve the appellation of uſeful, on account of ſome diſcoveries ſtumbled upon by chance, or that of curious, by hitting the fancy of thoſe who are fond of amuſing themſelves with elegant toys, would be very limited, and uncertain. For the art and apparatus uſed in experiments, often occaſion adventitious phænomena, and produce effects, ſomewhat diſtinct from thoſe which ariſe from the ſpontaneous operation of ſimple agents, both which only involve thoſe principles in deeper obſcurity; for, there may be an acceſſion of ſome foreign matter; and beſides, every degree of heat and cold has its correſponding effect on natural bodies, and every artificial application of either will raiſe the body a remove from its natural ſtate. It is from the obſervation of natural effects, and of the uſual and ſpontaneous operations of nature, that an extenſive, certain, and ſcientific knowledge is to be derived. Theſe operations therefore, and natural phænomena we chiefly attend to, from a conviction that nature is free, ſpontaneous, and copious, that ſhe does not affect to conceal her agents, but keeps them conſtantly in their proper functions, where they are always operating without reſerve. For which reaſon I doubt not but it will be found more inſtructive to take an extended view of ſome general operations of nature, and canvaſs their phænomena with ſcientific reaſoning, than to pry into a thouſand particular experiments with a ſcrutiny, which ſhould naturally be as ſhort-ſighted, as its object is minute and confined. When phænomena are ſpontaneous, they muſt be natural; when regularly reiterated, they muſt be from a fixt law; and when univerſal and copious, they muſt be from a predominant power or principle in nature. This acting principle of nature, muſt be a material ſubſtance, and could not act without its innate power. The peculiar eſſence this principle, is diſtinguiſhed from thoſe of other principles, by its propenſity or mode of action, which being found out, conducts us to the knowledge of the *material agent*. Theſe extended views would be loſt and interrupted, and could never be purſued, were a philoſopher to bury himſelf continually in prying into particular experiments. However, particular experiments will often be uſeful and even neceſſary, to ſcrutinize things more minutely, to make accurate diſtinctions, and to bring to the teſt properties diſcovered by general obſervation: they ſhall therefore be ſometimes adduced. But nature need never be put to the torture, while the effects ſhe ſpontaneouſly exhibits, and the grand operations ſhe performs, will anſwer our inquiries, and remove our doubts.

The following attempt muſt naturally ſhare thoſe imperfections which ſeem entailed upon all *beginnings*, and therefore claims that indulgence, which is as neceſſary for inventions, as it is due to their infant ſtate, and to the zeal of their authors for the improvement of ſcience. If the author of this eſſay, ſhall have the happineſs to point out a method, which men of leiſure and abilities may improve, and to give a ſpecimen of its utility for the advancement of the moſt noble of ſciences, his ambition will be gratified, and his labours rewarded.

ERRATA.

Page	Line	
4	16	for *vales* read *valves.*
32	3	for *culidary* read *culinary.*
110	16	for *or* read *and.*
295	6	read *or expand* with ſuch force.
299	20	for *quieſcence* read *adheſion.*
321	27	for *motion* read *notion.*
330	24	for *cauſes* read *cauſe.*
359	28	read *tranſmitted.*
381	6	for *him* read *the ſun.*
384	7	read is *ſeemingly* reflected.
6	25	preface, read eſſence *of* this.

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Pat. M'Halpin, Eſq. Sec. to the Lord Chan. 3 ſets.
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Mr. John Mullarky
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Mr. John Mathews
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Criſmas Wallis, Eſq.
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Y

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Rev. Mathew Young, F. T. C. D.

LECTURE I.

The firſt Principles of Philoſophy, with a Theory and Rules for Phyſical Inveſtigations.

SECTION I.

Firſt Principles and fundamental Axioms of Natural Philoſophy.

PHILOSOPHY, according to Pythagoras, is the ſtudy of wiſdom, or the knowledge of God, which Plato before had ſaid was the true philoſophy. Cicero defines a philoſopher thus: "*He who ſtudies to know the natures and cauſes of all things human and divine; and to attain to every good rule and method of life.*" Phyſics or natural philoſophy is the doctrine of bodies, and compriſes a knowledge of the powers, propenſities, and natural eſſence of matter; as alſo of the cauſes, and principles which actuate, or ſet it in motion.

Now ſince God is the Creator and original cauſe of all theſe beings, principles, and powers, and as, according to the Scriptures, the Heavens and earth, and the things they contain, proclaim his power and wiſdom, the ſtudy of phyſics, if duly applied, will coincide with the true philoſophy above deſcribed. And what ſhould be ſo deſirable to man, by nature grateful, as the contemplation of his Creator, and cauſe of his being? What knowledge ſo ſublime as that of his God? And what employment ſo commendable and elevated, as that of ſerving and praiſing his Divine Benefactor for his gifts, which are all that we are, and all that we have?

Natural reaſon declares, and experience proves that there cannot be an effect without a cauſe. Therefore all beings have had a firſt principle, or cauſe of exiſtence: which as it is firſt, muſt alſo be ſelf-exiſtent, and therefore eternal. This train of reaſoning is at once ſo obvious and convincing, that any attempt to elucidate, or confirm it, would only obſcure its evidence, and extenuate its force. But although it be ſuperfluous, and even unphiloſophic in a work of this nature, to enter into a diſcuſſion of the exiſtence of God; it is both pertinent and uſeful to expatiate a little on the attributes, which he has diſplayed in the univerſe. For example, in commencing the ſtudy of phyſics, it is highly neceſſary to have a juſt idea of the Divine Power, as far as it is attainable by human conception, for otherwiſe the timorous philoſopher will warp the ſtupendous works of the creation, or diminiſh the efficacy of nature's ſprings, in order to ſquare his ſyſtem with his contracted idea of the creative power.

Let us then contemplate for a moment the power of the Creator in the vaſt canopy of the Heavens, which ſurrounds us on all ſides, and in thoſe magnificent luminaries, which embelliſh it with unremitting luſtre; of that Creator, I ſay, whoſe omnipotence alone could endow the ſtars with their light and permanence, and ſpread out thoſe extenſive celeſtial ſpaces which they illuminate.

The inſtinct of animals, the underſtanding of *man* with all his mental powers, the ſucceſſion of ſeaſons with their various productions, the motion of animals, and the ſtructure of the univerſe, are magnificent proofs of the wiſdom and power of God. But it is not in theſe ſublime objects alone his attributes are diſplayed; his perfections are diſcoverable even in the ſmalleſt inſect. For examine a fly, or a midge, view its frame, texture, and machinery, the exact ſymetry of its parts, their aptitude to perform their peculiar functions, the hydrolic and pneumatic machinery (if we may uſe theſe expreſſions) of its inteſtines; ſurvey, or rather conceive its tubes and vales with the circulating fluids; what a ſcene of wonder here unfolds! If then we ſhould examine its ſenſitive organs; if we could diſſect its eye, diſcover its retina, fibres and nerves, ſhould we not confeſs that the works of God are as wonderful in the minuteſt creature, as in the moſt magnificent parts of the creation?

The royal David, either from reaſon or revelation, I ſhall not decide, was perſuaded that all nature, whether great or ſmall, diſplayed the power, wiſdom, and glory of God.

Hence he invited not only the luminaries of the Heavens, but even the beaſts of the field, to praiſe and glorify their God; why ſo? becauſe if the former proclaimed infinite power, the latter diſplayed wiſdom no leſs divine.

If ſo wonderful and ſublime be the machinery of the animal creation, and ſo admirable the regularity of material nature, what muſt we ſay of theſe refined and elevated powers called *inſtinct* and *thinking?* The bodies and operations of nature, being material, are objects of ſenſe, and ſubjects for experiment; nevertheleſs their chief powers exceed the comprehenſion of all philoſophers. Now if ſuch be the caſe in matters cognizable to ſenſe, who can comprehend the nature and eſſence of the ſublime powers above mentioned, which elude both ſenſe and experiment? He who reflects on theſe ſubjects, muſt neceſſarily break forth like Gallen the philoſopher; after long contemplating the regular frame, the texture, and exact ſymetry of a ſkeleton, with the proportions and deſign of all its parts, this renowned phyſician, though an Heathen, cries out, "there muſt exiſt a Supreme "Being, who governs the world; that "ſkeleton is the work of infinite wiſdom." His aſſertion was grounded on the wiſe diſpoſition and orderly arrangement of the parts; had he carried his views farther, and examined the original production of thoſe parts with equal attention, we ſhould have heard him explain their origin, as the inſpired Moſes has that of light, "The Lord ſaid, "Let there be light, and light was;" for thus only can man expreſs, what is beyond his conception to explain.

Atheiſts indeed pretend to explain the matter otherwiſe, but in a manner more inconceivable, and entirely unphyſical, by attributing the wonders of nature to a fortunate jumble. To theſe gentlemen I ſhall only beg leave to propoſe one queſtion. If I ſhall not ſay the ſublime powers of reaſon, or the uniform ſuggeſtions of inſtinct, I ſhall not ſay the machinery of the univerſe, or the animal œconomy, nor ſhall I even propoſe a reptile or inſect: but if the eye, or the ear of an animal ſurpaſs the power and invention of all the Atheiſts that have ever exiſted, with what face can they aſcribe the formation of all nature to a jumble of duſt, or atoms? In the deſarts of Aſia and Africa there are vaſt oceans of ſand, whereof a part is as ſmall as any epicurean atom. This ſand is of a gravitating nature, and beſides every other quality which Democritus[*] aſcribed to atoms, enjoys the additional advantages of air, light, heat, and moiſture, all which are favourable to animal, and vegetable productions; yet they produce nothing of either kind; not even an hoof or an horn, a tree or a leaf: on the contrary, they are found deſtructive to all ſuch productions, and only ſeem deſtined to confound Atheiſts, and atomic philoſophers.

It is needleſs to expatiate farther on a truth, whereof the evidence is ſo glaring, that it has gained the univerſal belief of all nations and countries. All civilized nations have left monuments behind of their having lived in this perſuaſion. Philoſophers, hiſtorians, and travellers, both ancient and modern, are vouchers for the barbarous and uncultivated parts of the globe; they all agree with Cicero and Plutarch, that there exiſts no nation ſo barbarous, no people ſo ignorant, as not to admit, and practice the worſhip of a Supreme Being. This ſeems the only notion, which, notwithſtanding the difference of ſituation, climate, and manners, the endleſs variety of cuſtoms, diſpoſitions and prejudices, has remained conſtant and permanent, amidſt infinite variations of manners and opinions: a permanence, which it could never have maintained, were it not rivetted in the nature of man. But this and many other proofs are out of the line of a natural philoſopher; what has been ſaid is abundantly ſufficient to eſtabliſh the exiſtence, power, and wiſdom of the Creator: which being laid down as a firſt principle, we ſhall deduce the following principal axioms, or univerſal truths, as grounds for our phyſical theory.

AXIOM I.

The works of the whole, and of every part of the creation, are perfect and compleat *.

ILLUSTRATION.

To ſay that the works of infinite power and wiſdom are not perfect and compleat, would be an abſurdity. For deficiency can

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* We call that being perfect and compleat which anſwers its deſign and purpoſe in nature.

only proceed from want of wiſdom to deſign and diſpoſe, or want of power to execute. Infinite power involves in its idea the power of creating and diſpoſing; infinite wiſdom includes deſign, prudence, and preſcience; the Creator's power produced whatever infinite wiſdom directed, and infinite wiſdom conceived and deviſed all that was requiſite for the perfection of the univerſe. Hence, the materials were ſufficient, the diſpoſition perfect, and the work compleat. Beſides the ſame power that has created, ſtill preſerves the univerſe, and for one great and conſtant end; for nothing was made in vain. The world, no doubt, was originally adapted to that great end: it is ſtill deſtined for the ſame; therefore it is ſtill equally perfect, its parts and order the ſame, and ſo ſhall continue, until the power, which produced and preſerves it, ſhall change, or annihilate it. To confirm our reaſoning by matter of fact, let us compare the world and its principal parts, at preſent, with what they have been at a diſtant period; if they be found uniform and conſtant, they give an ocular demonſtration of our axiom.

Let us therefore take into conſideration the various phænomena of nature, and compare the beings of each claſs with the correſponding orders of nature an hundred, or a thouſand years ago. Firſt, as to the revolution of the heavenly bodies, the number and order of the planets, the variety of ſeaſons, the ſucceſſion of day and night, and other ſtriking phænomena, we find them on record exactly conformable to our own experience. If any difference occur in the theory of aſtronomers, upon examination it will be found entirely confined to their various explanations; but their accounts of the apparent ſyſtem of nature are always the ſame.

If now we paſs to foſſils and minerals, we ſhall diſcover the ſame uniformity. We have ſeveral monuments of antiquity compoſed of metal; we have ſeveral ancient foſſils in the cabinets of the curious; and both have the ſtricteſt reſemblance to the correſponding ſubſtances of modern times. Whether metalurgiſts and chymiſts agree, or diſagree about their properties; we know at leaſt that iron and braſs were always uſeful in furniture and tillage; that ſilver and gold were uſed for money and ornament; that in general the ſame ſubſtances were always applied to the ſame purpoſes; which plainly ſhews that their nature and qualities were always the ſame. Vegetables conſiſted formerly of the ſame parts of which they are compoſed this day; they had roots, ſtems, leaves, and flowers. The ſame kind of tree in the ſame climate, produced the ſame kind of fruit, and was endowed with the ſame medicinal virtues, though men might not have been always equally ſkilful in extracting, and preparing them.

The various ſpecies of animals are now endowed with the ſame characteriſtics, which formerly diſtinguiſhed them. Ancient deſcriptions of their inſtinct and degrees of ſagacity are entirely conformable to thoſe of our times. If they were diſſected, anatomiſts might differ in their obſervations and theory; but the ſtructure of the animal would be found undoubtedly the ſame. It therefore appears that the ſeveral orders of beings, which conſtitute the different kingdoms of nature, are all the ſame now, as they have been at any former period. Hence it follows, that their principles and component ſubſtances muſt alſo be the ſame they have formerly been. Now theſe conſtituent ſubſtances and principles are the great elementary bodies of nature; therefore again, cauſes being as their effects, theſe elementary bodies are in nature, powers, and qualities the ſame as they have been originally formed.

Again, if we ſurvey the general ſyſtem of the univerſe, or carry our reſearches into any particular claſs of beings, we find them all diſpoſed for ſome great ends, and uniformly attaining their deſtination. We muſt therefore conclude, that the univerſe and its beings are perfect and compleat; and from the identity we have juſt eſtabliſhed, to wit, between the preſent and original ſtate of things, we may infer that they have always been, and were originally made perfect. And as the perfection of a work depends as much on the ſufficiency of materials, as on the ability of the artiſt, it follows, that the creative power gave exiſtence to every kind of ſubſtance, or matter, to every kind of power and principle neceſſary, or even uſeful for the perfection of his work. We have alſo obſerved that the phænomena and operations of nature are permanent and uniform;

from this permanency and uniformity of nature it appears, that infinite power and wiſdom ſtill preſerves them, and continues at once their exiſtence and perfection; which is a clear confirmation of our firſt axiom; of which the ſecond is an immediate conſequence.

AXIOM II.

There is no want in nature of either materials or principles, cauſes or powers, but a perfect ſufficiency of all that is neceſſary or uſeful to perform all her operations, and effects, and to attain the ends deſigned in the creation. This is evident from the omnipotence of the Creator, and the fitneſs of things.

SCHOLIUM.

Hence it evidently followeth, that as our bountiful God hath, through his infinite goodneſs, without any impulſe, or neceſſity, but of his own free will, created this our material nature and machinery; with her powers and beings, in ſome part or point of infinite ſpace, which exiſts in him, and at ſome inſtant of eternal duration, which is meaſured, and ſubſiſts only by him, the ſelf-exiſtent and eternal Being: Hence, I ſay, it followeth, that He only can change or deſtroy that material nature and machinery which he has created, and that, in ſuch other inſtant of eternal duration, as to himſelf only ſeems fit, according to the end which he deſigned in the creation. This concluſion correſponds directly with the ſentiments of the heathen philoſopher Dionyſius, who ſeeing an univerſal darkneſs on the day of our Saviour's crucifixion, at which time the moon was in oppoſition, and therefore a ſolar eclipſe impoſſible, according to the order of nature, cried out, "that the world was at an end, or that the God of nature ſuffered."

A X I O M III.

Matter, or any other ſubſtance, cannot be deſtroyed or annihilated, except by God the creator and conſerver thereof; nor can any change take place in its nature, beſides its ordinary courſe of mutation, without his divine order or permiſſion.

This permiſſion he can grant, and has really granted to his ſervants, as appears by the Scriptures.

SECTION II.

Neceſſary Obſervations, Phyſical Definitions and Propoſitions.

Before we proceed farther, it is neceſſary to premiſe definitions. Equivocal expreſſions are a perpetual ſource of obſcurity, which can only be avoided by previouſly explaining, and fixing the preciſe value and meaning of our terms. There are two kinds of definitions, to wit, nominal, and real. The former being definitions of words, may be premiſed, as they are arbitrary: but real definitions, which are ſo called, becauſe they explain not words, but things, muſt rather conclude than precede a phyſical work. The reaſon is this: A real definition explains the nature and qualities of the thing defined, which nature and qualities are only diſcovered after long inveſtigations, numerous experiments, and careful enquiries.

Many philoſophers have been led aſtray, in this particular, by a deſire of following the method of mathematics, which (by the way) is entirely different from that of phyſics. For definitions in mathematics are taken from idea, and are aſſumed as a ground of future ratiocination; whereas in phyſics, they are gathered from experiment, and not the ground, but the reſult of ratiocination. Examples of both will illuſtrate the matter. Commencing the ſtudy of mathematics, we reflect on our idea of a point, a line, a ſurface, or a ſolid, whereof certain diſtinctive characteriſtics immediately occur to the mind; theſe notions expreſſed in words form mathematical definitions, which are thus had without going farther than the mind itſelf. On the other hand, let a naturaliſt undertake an eſſay on air, in vain will he reflect on his idea of air: he never will, by his idea, diſcover its nature and powers. Will his idea ſuggeſt gravity, or compreſſibility? Will his underſtanding alone, unaided by his ſenſes, diſcover to him its elaſticity, or any other power it poſſeſſes? No; the diſcovery of its powers and qualities muſt be the reſult of obſervation and experience; conſequently both muſt precede his definitions.

It will be objected perhaps, that figure, magnitude and number are objects of idea, and yet of great conſequence in phyſics. It muſt be owned, that dimenſions and number are objects of idea, and yet have great influence in the mechanical operations, whether of art, or nature: but it likewiſe muſt be obſerved, they are neither principles of action, nor efficient cauſes in nature. Figure, for inſtance, will effect, that one body, with the ſame force impreſſed, ſhall penetrate another body, or medium faſter or ſlower; but without an active principle, figure can never produce motion. Number is ſomewhat of the ſame nature: a great number of impulſes from an agent will produce a greater effect, than a ſmaller number of the ſame impulſes: but number detached from the agent is a dead relation, which has no more influence in the operation, than the coiling of a watch ſpring has on the motion that inſues, which is entirely owing to the elaſticity of the ſpring. Wherefore this elaſticity, and not the coiling, is the principle of motion; for coil and roll up lead, thread, or any other body that is not elaſtic, and it ſhall not excite any motion. Here the figure of the coil, the number of its folds, or the magnitude of the roll, and quantity of matter, have not the leaſt efficacy, if ſome degree of elaſticity does not act.

Figure is a neutral mode of being, that regards the bounds only of body, and has no relation to its internal eſſence. It cannot therefore be a principle, or cauſe in the ſubſtance: for what idea of action can be conceived of ſuch a ſpiritleſs mode of being? The ſame alſo may be ſaid with regard to the figure of the ſmalleſt particle of matter, or of any number of them, as well as of the largeſt body.

Neither can magnitude, or number be any principle of action in bodies, being only comparative qualities of ſome being, or ſpecies pre-ſuppoſed to exiſt, in which exiſtence the real eſſence, principles and powers of the body muſt have been conſtituted, before number, or magnitude can be affirmed of it. Conſequently, number and magnitude are not firſt principles of action in body. But doubtleſs if there be any principle in a body, or any efficient cauſe in its conſtitution, the greater this is, the greater ſhall be its effect; and the ſame of number. But this is not true of figure, as the ſpring abovementioned likewiſe ſhews.

If fire or flame had not in its nature or eſſence an expanſive vigour, to ſend out its heat and light, we could not have a ſenſation of either at any diſtance, great, or ſmall; nor would the ſurrounding bodies be affected by it. If this active principle did not ſubſiſt, what advantage or effect could ariſe from the magnitude of fire, or the number of candles? But ſince it does exiſt in fire, the greater the fire, the greater the heat; and the greater the flame, or the more numerous the candles, the greater will be the light. But in all theſe caſes, figure, or any ſuch neutral and ſpiritleſs mode of being, has no efficacy in the principle of action, or ſource of power.

Therefore, ſince magnitude, figure and number (which are the ſole principles and objects of mathematics) are no wiſe included in the active principles, or operative cauſes of Nature; and ſince the inveſtigation of theſe principles and cauſes is the ſole end and intention of phyſics; we muſt conclude, that mathematical principles are uſeleſs in phyſics, until the real eſſence of body, or the powers and efficient cauſes of nature are explored.

But when theſe principles of action and efficient cauſes are diſcovered; when the places of their being, or reſidence, and modes of operation, or propenſities are determined, the application of mathematics will then, and not till then, be neceſſary to calculate and compute their qualities, their forces, and the effects of thoſe forces in the compoſition and reſolution of the motions ariſing from theſe active principles.

DEFINITION I.

Subſtance is that thing which we conceive to ſubſiſt of itſelf, independently of any other created being, or any particular mode or accident; and it is the ſupport of qualities, or powers, that are capable of producing ſimple ideas in us.

DEFINITION II.

Eſſence is that which conſtitutes or determines the nature of a thing, and is abſolutely neceſſary to its being. It is alſo defined, that whereby a thing is diſtinguiſhed from every other thing. Eſſence alſo involves in its idea the cauſe and ſource of powers; whence the ſubſtance and its eſſence may be conſidered as concrete, contextured and coexiſting. Which concrete ſubſtance we call the principle of all its powers: ſuch is light, which the Creator drew into exiſtence by his word of efficacy, to invigorate and warm the primordial matter, and to illuminate the creation.

DEFINITION III.

Quality is that affection of a thing which relates to our ſenſes, or that power which occaſions a thing to affect our ſenſes in this, or that manner; whence quality and faculty of the eſſence, or power of the ſubſtance may be looked upon as ſynonymous: for example, fire has an heating quality, which is a power eſſential to it.

DEFINITION IV.

Principle is the cauſe, ſource, or origin of a thing; whence God is the firſt principle.

Doubtleſs there are other principles ſecondary to him, but primary in nature, which he has made, to carry on her operations. Such are, the principle of the centrifugal force, (which is light or fire) and the principle of the centripetal force (whatever we ſhall find that to be) but when the word *principle* is employed, the acting ſubſtance and its eſſence are both implied.

DEFINITION V.

Agent is that principle of action, whereby a thing is done, or effected; that is, the efficient cauſe that has power to act on ſome other thing, whereby a change is produced therein: and the thing, whereon it acts, or which it changes, is called the *patient*.

Phyſical agents are thoſe which produce certain kinds of effects, but not their contraries; as fire which can heat, but cannot cool. We ſhall hereafter refer to this definition, as to an eſtabliſhed principle; it is therefore proper to make it a propoſition, and give it all the authority of demonſtration.

PROPOSITION I.

A phyſical agent cannot have two oppoſite propenſities, or powers to produce contrary effects,

A phyſical agent is a certain part, or ſpecies of matter, endowed by almighty God with a power to act according to a determined law, which is that of its eſſence, or nature. The tenor or mode of action, which the eſſence follows in conſequence of this law, we call its *propenſity*; and this propenſity is therefore indicative of the eſſence, which muſt act according to its determined mode, whether that be of propulſion (as in fire) or by attraction; but cannot have two oppoſite propenſities. For let us ſuppoſe this ſpecies, part, or particle of matter to have both propenſities, it muſt conſequently be endowed with both powers, which muſt be either equal, or unequal; if equal, being oppoſite, they muſt deſtroy each other's effect, in which caſe it has no power at all to act, and conſequently is not an agent; if unequal, the leſſer is overcome, and rendered ineffectual by the greater; and the exceſs of the greater being the only power that remains for action, this action muſt be according to the innate propenſity of that prevailing power. Whence the above propoſition.

A free agent is that which can do a thing, or not, as acting, not from propenſity, or pre-determination, but from choice. Such is the mind of man, that may either will, or not will the ſame thing.

A ſubſtance, which has a power of acting, we may call an *agent;* its power to act we may call the *eſſence* of that ſubſtance; and the mode, according to which this phyſical agent acts, we may call the *propenſity* of that power; as for inſtance, let fire be a certain active ſubſtance, then it is an agent, whoſe eſſence is expanſion; whoſe qualities are thoſe of heating, burning, and illuminating; and whoſe mode of action, or propenſity is by propulſion, as if it were, diverging from the centre in all directions to the ſurface, *i. e.* with centrifugal force. All which things we mean to inveſtigate from the effects and operations of nature, which collected from experience and obſervations, along with juſt experiments, ſhall be our chief *data* in the courſe of this our eſſay on phyſics.

DEFINITION VI.

A material ſubſtance that has no principle or power to act is a patient, and cannot be called an agent. However, though it be inactive, it has properties eſſential to it, and common with the material agents, as tangibility and extenſion, with other affections and modes educible from theſe, and depending on matter.

DEFINITION VII.

Palpability, or tangibility is a property eſſential to matter, whereby it becomes an object of ſome organ of ſenſe; and whereby we are ſenſible of its ſolidity, reſiſtance, action, reſt, and motion; of its bounds, figure, dimenſions and extenſion.

DEFINITION VIII.

Extenſion of a body is that property, whereby it occupies ſpace; whence its magnitude, dimenſions, limits, and figure; its diviſibility and parts; their quantity, &c, which are modes of being depending on matter.

DEFINITION IX.

Inactive matter (by its title) is void of all powers of action; whence it cannot be an agent, but a patient, or ſubject, whereon an agent may act, or be ſuperinduced, ſo as to incorporate, or endow the inactive, with the eſſence and qualities of that agent matter. But from this agent and its powers, the inert matter is again ſeparable, as being a diſtinct ſubſtance from it; for both were originally independent of each other, and each ſubſiſted by itſelf.

Now we ſhall lay down ſeveral propoſitions, fairly deduced from the principles we have eſtabliſhed, as an introduction to our phyſics. The principles I ſpeak of, *viz.* the wiſdom and power of the Creator, the perfection of the univerſe, and the immutability of all its parts, unleſs at his divine command, are the moſt certain, and at the ſame time, the moſt proper foundation for a phyſical theory. For it is only from the real principles and origin of nature, we can derive a true ſcientific knowledge of her cauſes, powers and operations: as is evident from the numberleſs chimerical and abſurd ſyſtems of the heathen philoſophers.

PROPOSITION II.

All the cauſes in nature are adequate and conſonant to their reſpective effects, as are her powers to the modes of their reſpective operations; *i. e.* effects are as their cauſes, an old axiom.

PROPOSITION III.

Hence, in nature, material effects muſt ariſe from material cauſes; material operations from material powers; and conſequently immaterial, or ſpiritual effects from ſpiritual cauſes; and (if we may ſay ſo) imaginary effects only from imaginary, or ideal cauſes.

This cannot be objected to, becauſe we ſee the *fitneſs of things* is univerſal in all parts of nature, and ſquares with the works of infinite power and wiſdom. Is it not upon the foundation of the *fitneſs of things*, which every one may ſee prevailing through nature, that philoſophers form the rational concatenation of cauſes and effects, from the firſt principles of nature to her ultimate productions, by the ſynthetic method of argument; or back again analytically from effect to cauſe, in order to inveſtigate her firſt principles? Upon what other baſis can we ground a ſyſtem, or have hopes of ſucceſs in our enquiries through the mazes of nature?

If the all-wiſe Creator had not formed, and purſued that rule, to wit, the *fitneſs of things*, whereby powers were fitted to their principles, and eſſences to their ſubſtances, accidents to their ſubjects, effects to their cauſes, and propenſities to their powers; what confuſion and diſorder would have been the conſequence among the beings of nature! Whereas, in all her kingdoms theſe beings are numberleſs; how could they be reduced to claſſes, tribes, or kinds? Or how could any number of them be arranged under one general head? Not only every animal would be fiſh, fleſh, and fowl; but partly of the vegetable nature, producing leaves, fruits, and flowers; partly of the foſſil nature, with its concretes of ſulphurs, ſalts and mercuries; and at the ſame time, a thinking ſubſtance, being compoſed of all kinds of exiſtences, without order, proportion, or diſtinction: the ſame might be ſaid of every circumſcribed body whatſoever: nor would the great elementary bodies fire, air, earth, and water, be then diſtinct. In that caſe, we could entertain no hopes of inveſtigation or philoſophizing from experience, or reaſon: there would be no uſe in experiments, or obſervations: we ſhould have no baſis for founding any ſyſtem or hypotheſis upon. Conſequntly the *fitneſs of things* is an univerſal rule in nature; otherwiſe all things would be in confuſion, as if they had ſprung from a concourſe of atoms.

We ſhall therefore extend our third propoſition, or make a fourth of greater latitude, that we may inveſtigate the object we have in view in the courſe of this work, with more eaſe and certainty.

PROPOSITION IV.

Subſtances and their eſſences are adequate, as are principles and their powers; alſo eſſences and their propenſities, as well as cauſes and effects.

* * *

SECTION III.

Newtonian rules compared with the foregoing propoſitions, their agreement, and diverſity; oppoſition in their tendency and in their conſequences.

THESE propoſitions have been fairly deduced from our notions of the divine attributes, and correſpond with that invariable rule, *viz*, the *fitneſs of things*, which an all-wiſe Being muſt have obſerved in the creation; and which alone can be a ſolid foundation for a phyſical ſyſtem, or a clue for inveſtigating the firſt principles of nature.

Sir Iſaac Newton has grounded his rules on another principle, to wit, the *ſimplicity of nature*, which is alſo conſonant to the wiſdom and works of the Creator. Now as the method of this illuſtrious author has met with univerſal and deſerved applauſe, it will be uſeful to aſſign the connection between his rules and our propoſitions; and alſo to point out the difference, if any there be, either in the tenor of the rules, or in the conſequences thence deduced. We will cite them from the Philoſophia Britanica, vol. 1, page 2.

RULE I.

"More cauſes of natural things are not to
"be admitted, than are both true and ſuffici-
"ent to explain the phænomena; for nature
"does nothing in vain, but is ſimple, and
"delights not in ſuperfluous cauſes of things.

RULE II.

"And therefore of natural effects of the
"ſame kind the ſame cauſes are to be aſſigned,

" as far as it can be done. As of reſpiration in
" man and beaſts; of the deſcent of ſtones in
" Europe and America; of light in a culidary
" fire, and in the ſun; and of the reflection
" of light in the earth and in the planets."

RULE III.

" The qualities of natural bodies which
" cannot be increaſed or diminiſhed, and
" agree to all bodies, on which experiments
" can be made, are to be reckoned as the
" qualities of all bodies whatſoever. Thus
" becauſe extenſion, diviſibility, hardneſs,
" impenetrability, mobility, *vis inertiæ*, and
" gravity are found in all bodies which fall
" under our cognizance, or inſpection, we
" may juſtly conclude, that they belong to
" all bodies whatſoever; and are therefore
" to be eſteemed the original and univerſal
" properties of all natural bodies."

RULE IV.

" In experimental philoſophy, propoſitions
" collected from the phænomena by induction
" are to be deemed (notwithſtanding contrary
" hypotheſes) either exactly, or very nearly true,
" till other phænomena occur, by which they

"may be rendered more accurate, or liable "to exception. This ought to be done, leſt "arguments of induction ſhould be de"ſtroyed by hypotheſes."

The following general concluſion is immediately drawn from theſe rules, *viz.* "If "according to theſe rules we take a ſurvey "of the viſible world, and ſtrictly examine "the nature of particular bodies, we ſhall "find reaſon to conclude that they all con"ſiſt of one and the ſame ſort of matter "and ſubſtance; and that all the diverſity "or difference we obſerve among them "ariſes from the various modifications, "and different connexion or adheſion "of the ſame primigenial particles of "matter."

The rules we have here recited are certainly juſt, and have an immediate tendency to the acquiſition and perfection of ſcience; but are not of themſelves ſufficient for that end: for their ſole object is to ſimplify the operations of nature, and deduce them all, if poſſible, from one common cauſe, as appears by the general concluſion annexed to theſe rules. But as too ſanguine a purſuit of ſimplicity might lead a philoſopher to confound things really diſtinct, rules are alſo neceſſary to enforce the neceſſity of diſtinctions, and to direct how to make them with propriety. The latter kind of rules will be uſeful limitations and illuſtrations of the former, as pointing out when theſe former may be applied with juſtice, and when their application would be erroneous. For as in morality, virtue may become vice, by being puſhed to exceſs, or practiſed with a blind undiſcerning zeal; ſo in philoſophy, maxims or rules of truth may become ſources of error, by being applied to improper objects, or urged beyond their natural extent. Now our propoſitions are the limitations and illuſtrations which appear to us moſt neceſſary; and however ſuperfluous they may at firſt ſeem, in the courſe of this work, they will be found applicable in ſcience, and of the moſt weighty importance.

Our ſecond and third propoſitions, to wit, *Cauſes are adequate to their effects, &c. Material effects ariſe from material cauſes, &c.* have an immediate relation to the ſecond rule, *viz. Of natural effects of the ſame kind the ſame cauſes are to be aſſigned, &c.*

and are implied both in it, and in the explanation that follows it. But experience proves that it is not enough to imply juſt limitations, it is neceſſary beſides, to aſſign them expreſsly; otherwiſe ſimplification may be puſhed to exceſs. Nature is ſimple indeed, but ſhe is alſo various in her operations; and although we are not to admit ſuperfluous cauſes, yet many cauſes muſt be neceſſarily admitted. Newton and reaſon preſcribe, that the ſame effects are to be attributed to the ſame cauſes; reſpiration, according to this author, in man and beaſts, ariſes from the ſame cauſe. The deſcent of ſtones in Europe and Africa alſo proceeds from the ſame cauſe. But doubtleſs, he never meant the cauſes of reſpiration, and of the deſcent of ſtones, to be one and the ſame. He was too judicious not to allow the elaſtic buoyant power of air, that inſpirits and expands the lungs of animals, to be entirely different from gravity, which ſhould rather tend to contract and bear them down. He therefore implied that oppoſite effects muſt have different cauſes, or cannot have the ſame. Conſequently reaſon authoriſes, and Sir Iſaac Newton coincides with thoſe of our propoſitions, which ſeem reſtrictive of his rules.

We ſhall now farther elucidate theſe propoſitions, ſhew their application, and perhaps extend their utility, by adding others equally certain and practical. The effects of light and gravity are ſtill more different from each other, than are thoſe of air and gravity. Light expands bodies, and enlarges their dimenſions. Gravity, being a ſpecies of attraction, contracts them, and leſſens their dimenſions. The one is a clog upon matter, the other animates and revives it; as we ſee by the effects of the ſun's heat and light at the return of ſpring, and during the ſummer ſeaſon: therefore, according to the firſt propoſition, theſe effects are produced by different cauſes. Again, theſe effects are material, therefore their immediate cauſes, according to the third propoſition, are alſo material; that is, tangible ſubſtances. 3dly, By the fourth propoſition the ſubſtance is adequate to the eſſence, and the eſſence adequate to the propenſity. Conſequently the ſubſtance of light, or fire, which opens and enlarges the dimenſions of body, muſt have a power adequate, that is, an expanſive eſſence, and the propenſity of this eſſence muſt be adequate to expanſion, that is, muſt be centrifugal. By the ſame propoſition, as the ſubſtance of gravity brings the particles of matter together, and leſſens its dimenſions, its eſſence muſt be adequate to ſuch a ſubſtance; that is, convergent, and its propenſity centripetal. Which two examples are a full illuſtration of our fourth propoſition.

It is clear from theſe examples, and from the tenor of theſe propoſitions, that their ſole ſpirit and tendency is to form accurate diſtinctions, which is in a great meaſure the buſineſs of philoſophy: for it is only by ſurveying nature with a vigilant eye, by ranging her beings and operations in their proper claſſes, and by remarking their agreements and diſtinctions, that we can hope to inveſtigate her ſprings, or firſt principles. The ſpirit of Newton's rules on the other hand is to ſimplify, and if poſſible, to deduce all effects from the ſame cauſe: which method, however juſt, was dangerous in its applicacation, as it induced his followers not to ſearch after, nor admit more principles than one, although more manifeſtly diſplay themſelves in nature. Two examples will ſhew the different tendencies of both methods.

Conformably to the ſpirit of the Newtonian rules, it is ſaid in the general concluſion, cited (p. 33,) that all bodies conſiſt of one and the ſame kind of matter, and that all their varieties proceed from various modifications of the ſame particles. It is alſo concluded in the explanation of the third rule, that gravity, *vis inertiæ*, &c. are the properties of all bodies. But our rules not only render us more circumſpect in adopting ſuch concluſions, but even induce us to reject them. For as to the firſt, we know that the immediate and phyſical cauſes of all material effects are themſelves material; that therefore, the cauſe of heat, light and expanſion, or the ſubſtance producing thoſe effects is material. Again, as by our firſt propoſition, one phyſical agent, or material cauſe, cannot produce two contrary effects; therefore attraction, which draws together, and expanſion, which ſeperates, cannot proceed from the ſame cauſe. Conſequently, as theſe two operations are ſeen to obtain in material nature, they have two diſtinct material cauſes, whoſe eſſences and propenſities are oppoſite; we therefore diſallow the general concluſion above cited, and pronounce that experience exhibits, at leaſt, two kinds of matter in nature: for oppoſite propenſities muſt ariſe from different eſſences, *i. e.* different ſubſtances, conſequently different principles.

Let us now, according to the ſame method, examine the ſecond aſſertion we have quoted, to wit, that *vis inertiæ*, with the other properties there enumerated, is common to all bodies. Sir Iſaac Newton declares in many parts of his works, that there is in material nature an active power called *attraction;* nor can any one deny that a force is exerted in nature, which tends to bring things together. It may indeed be doubted, whether this force proceeds from attraction or compreſſion, *i. e.* impulſion; for even Newton himſelf was in doubt about that, as is clear from theſe words in his 31ſt query; "What I call *attraction* may be performed "by impulſe, or by ſome other means un-"known to me," ſo that until this queſtion be determined, we ſhall call attraction the *centripetal* force; for ſuch is its tendency, whether its cauſe be attractive or impulſive. But let this be as it may, certain it is, that a ſtrong centripetal force acts upon bodies throughout the univerſe. It is alſo allowed that there is another power in nature, namely, that of fire or light, which expands or dilates bodies, ſeparating their parts with a centrifugal force. This principle of expanſion, according to Boerhaave, is ſo univerſal, that there is not a body, or ſpace in nature, which has not its fires, though ſometimes latent until excited. The univerſality, materiality and expanſion of light we ſhall hereafter expatiate on; but for the preſent we ſhall admit them, as they are points that few call in queſtion. Wherefore light or fire, the principle of the centrifugal force, being a material ſubſtance, ſhould we not alſo conclude, as well from analogy, as from our third propoſition, that the centripetal force, which is equally powerful in producing material effects, alſo ariſes from a material ſubſtance. Otherwiſe, contrary to the ſame third propoſition, we ſhould impute real and material effects, to imaginary or ideal cauſes. Now as theſe two principles of action ſeem to be the chief ſprings of nature, whereby all her operations are effected, we ſhall call them her *material agents*.

There are therefore in nature two material agents, of prodigious efficacy, and of oppoſite propenſities. Theſe agents are acting material ſubſtances; for a power without a ſubſtance exerting it, is only an abſtract conception of the mind, not any thing really exiſting. And if the eſſence or power of a ſubſtance be active, according to our fourth propoſition, and to reaſon, the ſubſtance muſt likewiſe be active, otherwiſe two abſurdities would follow: *viz.* that the eſſence, power, or diſtinguiſhing character of a ſubſtance could be ſeparated from it; and 2dly, that a power or eſſence of matter ſhould act independent of its ſupporting ſubſtance; in which caſe, the power ſhould want its material efficacy and impelling force, being no longer tangible, extended and ſolid; and muſt either be ſuppoſed to act upon matter, as ſpirit does, or elſe to create for itſelf a new kind of matter, to form an impelling force, and render it tangible *, which is equally abſurd.

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* We have defined tangibility an eſſential property of matter, whereby it affects our organs. By this we do not inſinuate that it is eſſential to all matter to affect our organs; that would be more than we could ſafely

Conſequently, the two ſpecies of matter, endowed with theſe oppoſite powers and tendencies to act, cannot be called inert; becauſe they have in themſelves a power of motion and of action, which gives motion to inert matter, and which produces the operations of nature, as will hereafter appear. We muſt therefore ſet limits to the property of inertneſs, which the preſent generalizing method of philoſophizing has rendered univerſal. And even though there ſhould be intervals of time, and particular circumſtances, in which ſome part or parts of theſe matters ceaſe to act, and no longer exert their powers; yet, ſuch parts under theſe circumſtances, or during that ſuſpenſion of activity, are not to be called inert matter; becauſe they ſtill retain their eſſence, or the ſource of their active properties, which diſtinguiſh them from inert matter, *i. e.* from matter void of power. For even

aſſert: we only mean that tangibility gives to the matter we are acquainted with the *capability* of affecting our organs. But perhaps, a more refined ſpecies of matter might be tangible and ſolid, without affecting them. This being remarked, tangibility may be conſidered as an eſſential difference between matter and ſpirit.

the ſoul of man, of rational eſſence, may ſometimes deſiſt from thinking and reaſoning; yet, in that interval of ſleep, drowſideſs, or whatever elſe be the cauſe of its inaction, it cannot be called an inactive being; becauſe during its inaction it ſtill preſerves its natural eſſence, which involves its faculties of thinking and reaſoning, and every thing which conſtitutes an active ſpiritual ſubſtance. In the ſame manner the matters endowed with active propenſities, even during the ſuſpenſion of their active powers, are eſſentially different from inert matter.

There is but one way of reconciling the active powers diſcovered in matter with the prevailing notion of univerſal inertneſs (I ſay, the prevailing notion, becauſe matter is at preſent defined, *a ſubſtance extended, ſolid, and perfectly inactive,*) this way is to ſuppoſe, that God created matter at firſt inert, and after he had given it exiſtence in that ſtate, then endowed it with certain powers to operate. Thus, a ſuppoſition of its original inertneſs may juſtify the preſent definition, Whether metaphyſicians have a privilege to form ſuch a ſuppoſition as this, or where they fix their ſtandard for defining the nature of a ſubſtance, I ſhall not determine, farther than what the preſent definition ſeems to intimate, which appears to have been framed by ſome ſuch ſubtile ſpeculators. But natural philoſophers, I am perſuaded, ſhould define matter according to its nature, *i. e.* according to the powers and properties they find it endowed with, which are to be diſcovered by experiment. Thus, experiment reports the ſenſible qualities; the ſenſible qualities diſcover the power or property producing ſuch qualities; and this power or property determines the eſſence, or diſtinctive nature of the material ſubſtance experimented upon. Experiments, therefore, are our only guides to the nature of matter, according to Newton's fourth rule, which directs us to oppoſe hypothetic arguments by thoſe grounded on experiment. Conſequently, we muſt found our definitions on the properties we now find matter endowed with, not on what it may be ſuppoſed to have been in a fancied primeval ſtate. Wherefore we are to call that matter only inert, in which we find no principle, or power to operate, without the impulſe or exertion of an external cauſe. And wherever we find in any body any power of action, we muſt conclude that body has in its compoſition ſome active matter.

The ſuppoſition of an univerſal primeval inertneſs is not only arbitrary and improper in phyſics, but alſo falſe and inconſiſtent. For it behoved the wiſdom of God, to create ſubſtances, whether material, or immaterial, endowed with their diſtinctive natures and eſſences coeval with their exiſtence; and we find in fact that He hath done ſo. For when the matters of the heavens and of the earth were created in a confuſed heap, or chaos without form, and overwhelmed with darkneſs, the Lord ſaid, "Let there be "light, and there was light," which probably is the laſt kind of matter He gave exiſtence to. Now as this ſubſtance was light the inſtant it came into being, it muſt have that inſtant been endowed with all the powers and properties, which conſtitute and characterize the nature of light; theſe properties were alſo neceſſary for the functions it was deſtined to perform, *viz.* to warm and meliorate the chaotic heap, for producing the various beings of the univerſe, and alſo to illuminate the creation.

The immaterial ſubſtance of the human ſoul, we alſo learn from holy writ, was adorned with its ſublime power or eſſence at the time of its creation; for juſt after we are informed that God breathed into Adam a living ſoul, we hear *that awful law* enacted and explained to him, which was to determine his fate, and that of his poſterity. Now to receive from his Creator ſo important a precept, he ſhould certainly enjoy the moſt perfect uſe of every mental faculty. Since therefore we are aſſured that theſe ſubſtances, and their reſpective eſſential properties received exiſtence together, ſhall we not conclude, conformably to the omnipotence of God, and the uniformity of his operations, that every other eſſence was likewiſe coeval with the ſubſtance to which it belongs. Nothing can be objected to this well grounded concluſion, but mere ſuppoſition, which therefore, according to the fourth Newtonian rule, ſhould be immediately rejected, and the contrary concluſion adopted as true.

SECTION IV.

New remarks on the diſtinction of ſubſtances, fifth propoſition; conformity of theſe inveſtigations to the deſires of Newton; neceſſity thereof from the nature of his works.

PURSUANT to the ſame principle, we muſt alſo conclude, that the matter originally created inert ſtill continues eſſentially inert; for if we ſhould ſuppoſe inert matter endowed with active powers, theſe powers ſhould act without their ſubſtance, or detached and at ſome diſtance from it, therefore without materiality; in which caſes the powers would be impalpable, unreſiſting, and unſolid, and conſequently unfit to produce material effects, or operations. Yet as in the compoſition of bodies it may ſometimes be blended with active matter, in this ſenſe, it may be incorporated with powers and propenſities, which, however, though ſuperinduced upon it, cannot be conſidered as proper to it; being entirely peculiar to, and inſeparable from the active material ſubſtance, or ſubſtances to which they are eſſential.

Thus through the materiality of the ſubſtance, which ſupports lively powers, it has a natural alliance with inert matter, whereby the latter may be impregnated with powers and qualities in a body compoſed of both. Again, its activity renders it proper to exert theſe powers, ſo that while ſuch active matter either inheres in inert matter, or is aſſociated therewith, it forms a link of union between the lively powers and the inert matter. Hence properties entirely oppoſite, and even incompatible in the ſame ſubſtance, may be found in the ſame body; becauſe different ſpecies of matter, with their different eſſences, may enter into its compoſition. For inſtance, a ſtone is heavy, which indicates there is gravitating matter in it; ſparks of fire or light come from it, when excited by friction or colliſion, which ſhews that it contains that ſpecies of matter; it alſo gives ſigns of inertneſs, and therefore has in its compoſition inert matter.

Hence it appears that the different principles of body are united or ſeparated by the union or ſeparation of their concretes; *i. e.* that the ſubſtance and eſſence of one principle is united with, or ſeparated from the ſubſtance and eſſence of another, the ſubſtance and eſſence of the ſame principle being inſeparable. For example, the pure white aſhes of paper, or of any vegetable or animal body we know to be void of coheſion, ſmell, taſte and all other qualities; they may be therefore conſidered as inert matter. Now if a quantity of theſe aſhes be mixed with oil or tallow (which have many qualities, and afford light and heat when inflamed) they will kindle and afford light, although before the mixture they could not be any how affected by fire. But when all the oil or tallow ſhall be carried off by fire, the aſhes ſhall again be found in their original ſtate of inertneſs. Thus the two ſubſtances in their union and ſeparation, are always accompanied with their reſpective properties. Whence we may infer a fifth propoſition eaſily deducible from the preceding obſervations.

PROPOSITION V.

Eſſences are diſtinguiſhed by their propenſities, and are inſeparable from their reſpective ſubſtances; but diſtinct ſubſtances are ſeparable from each other, and conſequently carry with them their proper eſſences and propenſities.

All parts of this propoſition may be deduced from the foregoing remarks, and are almoſt obvious enough to be called ſelf-evident. For 1ſt, As an eſſence is known from its propenſity or action, one eſſence is diſtinguiſhed from another by its different mode of action, that is, by its different propenſity. 2dly, If a material eſſence were ſeparated from its ſupporting ſubſtance, it would loſe its *materiality*, and, ſubſiſting by itſelf, muſt either become a ſpirit, or otherwiſe a non-entity; but both theſe ſuppoſitions are abſurd; therefore eſſences are inſeparable from their reſpective ſubſtances, as *per* fifth propoſition. 3dly, The diſtinction of ſubſtances implies the poſſibility of their exiſting independent of each other, and therefore of their being ſeparated: conſequently diſtinct ſubſtances are ſeparable from each other. 4thly, That in the ſeparation each ſubſtance carries off its reſpective eſſence and propenſity, is an immediate conſequence of the ſecond part, to wit, eſſences are inſeparable from their reſpective ſubſtances; as will hereafter appear from future experiments.

Hence the human ſoul is a different ſubſtance from the body, from which it is ſeparated by death. This is ſtill more clear from ſome former propoſitions; for with the ſmalleſt attention to the operations of the mind, we find them inconſiſtent with matter, and unimputable even to the moſt ſubtile air, or moſt active flame; therefore by the fourth and fifth propoſitions, the power and principle, eſſence and ſubſtance producing theſe immaterial operations, muſt be ſpiritual, and infinitely different from material ſubſtance, having no affinity therewith, except that both are limited, and have a common cauſe of exiſtence, to wit, God. This ſpiritual thinking ſubſtance however, being limited, (as every man is conſcious from the bounds of his underſtanding, and the ſmall extent of all his faculties) is infinitely different from the Divine Being, which is infinite in every attribute, and every poſſible excellence.

Thus we have diſtinguiſhed three beings that really and actually exiſt, *viz.* The Divine, which being intelligent, muſt be ſpiritual, in which it agrees with the intelligent being in man, but it is infinitely different in eſſence and attributes; theſe of the Divinity being infinitely more excellent, who can create ſubſtances and powers, and bring them into exiſtence faſter than man can conceive a thought, or expreſs it by a word. The ſecond being is the human ſoul, endowed with the ſublime faculty of reaſoning, and even capable of contemplating the Creator's perfections. The third is the material being, that is, all things that are palpable, and have extenſion, which properly are called *matter.* This agrees with the intelligent ſpirit, or ſoul of man in this one thing, that both are limited in all their attributes reſpectively, and conſequently in their ſubſtances; but in nature, eſſence and powers, they are infinitely different.

From the general tenor of this lecture it may appear, that this eſſay is likely to diſagree with ſome tenets of the reigning philoſophy. It muſt not however be imagined, that an enquiry of this nature is either derogatory from the merit, or contrary to the ſpirit of Sir Iſaac Newton's works; for a perſon thoroughly converſant with them, will immediately perceive that a reſearch of this nature was highly conformable to his wiſhes. This he intimates in the few lines preceding the firſt of his queries. "Since I have not fi-"niſhed this part of my deſign, I ſhall con-"clude with propoſing ſome queries in order "to a further ſearch to be made by others." The various ſubjects of his queries, ſuch as the reflection and refraction of light, and its fringes, the reality of his ætherial medium, a vacuum in the heavens, atoms, their gravity, &c. were therefore matters that he wiſhed ſhould be farther examined by others. As for the three laſt articles, he acknowledges them to have been the phyſical principles of the ancients.

In propoſing theſe queries, he ſeems to have adopted the method recommended by the wiſe Lord Verulan, who conſidered a calender of doubts as a moſt efficacious means of improving ſcience. Doctor Shaw, who commented on Bacon's works, produces Sir Iſaac Newton's queries, as almoſt the only eſſay extant towards forming ſuch a calender. But to be more particular, we have already ſhewn that he doubted whether attraction, or (to ſpeak more properly), the tendency of bodies towards each other, was the effect of an impelling or of an attracting force; he expreſſes himſelf in this manner: 31ſt query, "What "I call attraction may be performed by im-"pulſe, or by ſome other means unknown "to me. I uſe the word here to ſignify "only in general any force, by which bodies "tend towards one another, whatever be "the cauſe; for we muſt learn from the phæ-"nomena of nature, what bodies attract "one another, and what are the laws and "properties of attraction, before we enquire "the cauſe by which the attraction is per-"formed."

Hence it appears that Newton, in this particular, rather acted in the capacity of a mathematician, who computes forces, and calculates their effects, than of a philoſopher who pries into the cauſes or agents exerting ſuch forces; and natural philoſophy muſt continue very imperfect, while a principal agent in nature thus remains totally unknown, and only ſupplied by a name expreſſing its apparent effect. Newton not only doubted of the propenſity of its cauſe, but alſo had ſome ſuſpicions that the cauſe of gravity reſided not in all bodies, but was exerted upon the reſt by ſome one particular agent, which his commentators were free to call *material* or *immaterial*, as they thought moſt plauſible. This may clearly be inferred from many places, we ſhall quote two. In the ſecond advertiſement prefixed to the ſecond edition of his optics, he ſpeaks as follows: "In this "ſecond edition of theſe optics, I have omitted the mathematical tracts publiſhed at the "end of the former edition, as not belonging "to the ſubject, and at the end of the third "book I have added ſome queſtions; and to "ſhew that I do not take gravity for an eſſential property of bodies, I have added "one queſtion concerning its cauſe, chooſing "to propoſe it by way of queſtion, becauſe I "am not ſatisfied about it for want of experiment."

Secondly, that he doubted whether this property did not proceed from the action of a particular ſpecies of matter, is apparent from his 31ſt query, (page 365) "There are "agents in nature capable of making the "particles of matter ſtick together by very "ſtrong attractions, and it is the buſineſs of "experimental philoſophy to find them out." From which it is clear, that Newton has left the buſineſs of natural philoſophy entirely unfiniſhed; for he has never diſcovered, nor even hinted what theſe agents are which occaſion attraction, except by conjectures, which he propoſes for farther examination: as an example of this, we ſhall quote a part of his 21ſt query.

"Is not this (ætherial) medium much "rarer within the denſe bodies of the ſun, "ſtars, planets and comets, than in the "empty celeſtial ſpaces between them? And "in paſſing from them to great diſtances, "doth it not grow denſer and denſer perpetually, and thereby cauſe the gravity of "thoſe great bodies towards one another, "and of their parts towards the bodies, every "body endeavouring to go from the denſer

" parts of the medium towards the rarer? " For if this medium be rarer within the " ſun's body than at its ſurface, and rarer " there than at the hundredth part of an inch " from its body, and rarer there than at the " fiftieth part of an inch from its body, and " rarer there than at the orb of Saturn, I " ſee no reaſon why the increaſe of denſity " ſhould ſtop any where, and not rather be " continued through all diſtances from the " Sun to Saturn and beyond. And though " this increaſe of denſity may at ſome diſtances be exceeding ſlow, yet if the elaſtic force of this medium be exceeding " great, it may ſuffice to impel bodies from " the denſer parts of the medium towards the " rarer, with all that power which we call " gravity." Such is Sir Iſaac Newton's conjecture concerning the material cauſe of gravity, and the mechanical explanation of its effects.

The phyſical principles of Sir Iſaac Newton are therefore unſettled, and juſtly propoſed by that author for future diſcuſſion; his mathematical principles, (for ſo he ſtiles them in the beginning of the third book of his *Principia*, where he ſpeaks thus, " In the

“ preceding books I have laid down the “ principles of philoſophy; *principles not phi-* “ *loſophical but mathematical,*”) his mathematical principles, I ſay, on the other hand, have been puſhed to the higheſt perfection. It is therefore moſt uſeful for compleating the ſcience, which his labours have ſo much forwarded, to reviſe and diſcuſs his phyſical tenets, ſo as to remove all ambiguity, and either render their reality incontrovertible, by a phyſical inveſtigation of their exiſtence, or elſe make what additions thereto may be found neceſſary by experimental reſearches through nature.

One happineſs indeed which attends the works of Sir Iſaac is, that his mathematical theory is expoſed to no riſk, except that it may be too extenſively applied; for this judicious author founded his calculations on general phænomena, not on the nature of the cauſe he aſſumed: provided then his mathematical theory be applied to proper objects, it is a matter of indifference to him, whether the phænomena of attraction be produced by a drawing or an impelling cauſe; the mathematical law is collected from phænomena, and is the true law of the force, whatever phyſical inveſtigation may diſcover that force or its agent to be.

Having now laid a foundation for our inveſtigations, and made the reader ſomewhat acquainted with the method we intend to purſue, we ſhall conclude this lecture by a few words in defence of our introduction. Our obſervations on ſpiritual ſubſtance, with what we have ſaid on the exiſtence and attributes of God, may appear a digreſſion foreign to our ſubject; but whoſoever conſiders philoſophy in its proper light, will not condemn ſuch a deviation; for beſides that God is the cauſe of cauſes, and conſequently the true object of philoſophy, it is requiſite to have an idea of him, in order to inveſtigate properly his works; for without a perſuaſion of the divine power and wiſdom, the philoſopher will contract the creation, diminiſh its powers, and extenuate its grandeur, in order to ſquare effects with a limited and miſconceived cauſe.

It is alſo uſeful on every occaſion to purge philoſophy of the ſhameful errors with which it is too often defiled, and to explain every tenet which malice or ignorance could pervert, ſo as to guard the whole againſt all interpretations that might favour immorality or irreligion. But theſe were not our only motives to adopt this uncommon method. Our propoſitions, axioms and firſt principles are founded on God and his attributes; ſo that we are neceſſitated to follow this plan. For the perfection, uniformity and regularity of nature, are the true guides of a philoſopher, which if he will not take for granted, he muſt trace them to their ſource, to wit, the wiſdom and power of the Creator. This we have done, and having, we preſume, well eſtabliſhed our principles, ſhall now proceed to inveſtigate nature.

LECTURE II.

Inertneſs of Matter, Univerſality, Exiſtence, Laws and Origin of that Property examined.

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SECTION I.

Definition of Matter, all Matter extended and ſolid; but the univerſal Inertneſs of Matter an unreaſonable and falſe Suppoſition.

MATTER is, at preſent, defined by philoſophers, "a ſubſtance extended, ſolid, "and perfectly inactive." It is undoubtedly true, that every kind of matter is extended and ſolid; theſe two properties being ſo eſſential to all matter, that without them we can conceive no idea either of a material ſubſtance, or of a material operation: for without extenſion, body cannot be conceived to have dimenſions, or to occupy ſpace; and without ſolidity, one body cannot be underſtood to act upon another, ſo as to produce motion, or give reſiſtance. Nay, without theſe properties, all the beings and operations of material nature would eſcape our knowledge; for external objects only affect our ſenſes, either by their own immediate contact, as in feeling, or by the impulſe of ſome intervening medium, as in ſeeing; both which means of receiving ſenſation neceſſarily require extenſion and ſolidity in the object of ſenſe.

That extenſion and ſolidity are requiſite to excite feeling is immediately evident, ſince we only receive this ſenſation by the action, or re-action of ſome reſiſting ſubſtance upon the ſenſitive fibres of the organ. But the neceſſity of extenſion and ſolidity for ſeeing, hearing and ſmelling, is not ſo obvious, nor ſo generally known. All philoſophers indeed allow, that an object becomes viſible only by the light which flows from it, and which having entered the eye, forms a perfect image of the object on the retina. This they prove by the experiment on the eye of an ox, or of any other animal recently killed, when duly prepared and diſpoſed for the purpoſe. And even the moſt illiterate perſon may perceive that light is the agent, which produces viſion, from his loſing ſight of an object, as ſoon as the light is intercepted, which ſhould render it viſible: this he may be convinced of by cloſing his eyes, or by placing his hand between them and the object; for in either caſe, the rays of light coming from the object are prevented from entering the eye. Such is the dependence of viſion upon light, that at night, if the lights in a room be extinguiſhed, every thing becomes inſtantly inviſible therein. And, on this account, every part of the viſual organ has ſome reference to light: the pupil, it is clear, is deſtined to admit light, the humours of the eye to refract and convene it, and the retina to receive the impreſſion of the object.

Now we know that light is a material ſubſtance, from its being a transformation of tallow, wax, oil, or other ſuch material ſubſtances; for theſe matters when burned, are not annihilated, (the annihilation of ſubſtance not being an operation of nature, but an exertion of infinite power, confined to God alone) they are only reduced to a more exalted and ſubtile form, to wit, that of light. That the ſolar light is material, is alſo evident from its violent action and powerful effects upon bodies in the focus of a burning glaſs; and likewiſe from the reflection and refraction it ſuffers in meeting or pervading other bodies; for a ſpiritual ſubſtance cannot be conceived to be reflected or refracted by the action or reſiſtance of matter.

Smelling is produced by the actual touch of an effluvium proceeding from an odorific body, and acting upon the olfactory nerves. Hearing is excited by the impulſive tremours of air, in the following manner: the tremours of the ſounding body excite a tremulous motion in the air, which acting on the drum of the ear, communicates like tremours to the elaſtic ſpecies thereof, and thus a ſenſation of ſound is excited. Thus our organs, being paſſive and material, every ſenſation is excited by the touch, or impulſe of another material ſubſtance; tangibility therefore, which implies ſolidity and extenſion, is neceſſary in the ſubſtance that excites ſenſation. Conſequently, without theſe properties we ſhould have no intimation that external bodies exiſt: for it is only by ſenſation we are apprized of their exiſtence. Hence, we muſt conclude from all our ſenſations, that matter is tangible, *i. e.* extended and ſolid.

But that all matter is perfectly inactive, is a part of this definition which cannot be admitted, for two general reaſons.

Firſt, If all matter was perfectly inactive, we could not be ſenſible of its exiſtence; at leaſt we ſhould have no ſenſation of thoſe bodies which are beyond the reach of feeling: for ſuch diſtant bodies only affect our organs, which are of a neutral paſſive nature, either by the action of an effluvium, or of ſome intervening medium, as we have ſeen above. Now, our corporeal organs being matter, can only be affected by another material ſubſtance; therefore, the effluvium, or medium by which they are affected is matter. And this material ſubſtance, which affects them, cannot be inert, as it acts upon them: the matter therefore which gives ſenſation of diſtant bodies cannot be inert.

Secondly, If all matter was inert, all nature would be torpid and dead; there would be no vigour, or principle of action in the univerſe, and conſequently no operation. Whence, in this caſe, the action of fire, air and water? Whence the motion and circulation of fluids neceſſary for vegetation and animal life? Whence, in a word, all the operations of nature?

It is amazing how this idea of all matter's being torpid and inactive, could have entered into the mind of any philoſopher, or how a tenet ſo repugnant to reaſon, and ſo contrary to experience, could have taken place in any ſyſtem of phyſics: for it is certainly repugnant to reaſon to ſuppoſe, that the Divine Power is as much exerted every moment ſince the creation, as it was in bringing the univerſe into being; as if the ſame power neceſſary to produce a work was alſo neceſſary to preſerve it. This, indeed, might be ſaid with ſome juſtice of a phyſical cauſe and its effects: but ſuch imbetility cannot be aſcribed to an Almighty Agent.

Even man, whoſe wiſdom, powers and ability bear no proportion to thoſe of his Creator, can contrive a watch, an engine, or ſome ſyſtem of mechanic powers, and ſhall adapt thereto a ſpring, which will continue its motions for a certain time, though he were a thouſand miles off, as well as if he were preſent. We muſt therefore conclude, that Infinite Power and Wiſdom has at the creation made agents and active principles, to perpetuate the operations of nature whilſt the univerſe was to laſt. This idea is certainly more conſonant to the divine attributes, than to imagine, that the divinity is conſtantly impelling the particles of matter, and producing thoſe lively operations, which we every where behold throughout material nature. But unleſs we admit ſome matter endowed with natural activity, and an innate propenſity to move according to a certain direction, every action and motion in nature muſt ariſe from a conſtant ſupernatural interpoſition, which ſeems derogatory of the wiſdom and power of the Creator. Doubtleſs then God, in the creation, brought forth each being endowed with the power and propenſity adapted to its deſtination. No materials were wanting to Infinite Power; no deficiency of ſkill can be imputed to Infinite Wiſdom. If, therefore, the art and perfection of human contrivance be diſplayed in the many and permanent effects produced by a ſingle ſpring, or principle of action; certainly it is more conſonant to Infinite Power and Wiſdom, to have created originally one or more ſpecies of active matter impreſſed with a certain invariable propenſity to ſerve as permanent agents, or ſprings in the machinery of the univerſe, than by conſtant and reiterated acts of his Divine will, to be continually giving various motions to all the particles of matter.

But it is not from reaſon alone we conclude that Almighty God has framed ſuch agents in material nature. The fact is clear from experience; for the innate elaſticity of the ſprings, which mechanics employ, or the activity and power of fire, by which they are wrought and tempered, point out material agents in nature, whoſe power and propenſity were made at the creation, and continue invariable to this day. The Sun which revives vegetation in ſpring, which renews animal vigour, and cheers all nature by its influence, muſt certainly be an agent in nature. And although he be the moſt conſpicuous, he is not the only agent in the univerſe: for he has but one propenſity, or mode of action, which invariably preſerves the ſame tenor. There muſt alſo be other material agents of different tenors to effect thoſe things that are inconſiſtent with the ſun's power: for every material agent has its peculiar eſſence, from whoſe ſtated propenſity it cannot vary.

Man, indeed, not being purely material, was made a free agent, capable of meriting rewards or puniſhment: wherefore his faculties, which are peculiar to his nature, are under the dominion of his will. But brute animals muſt yeild to the inſtinct proper to their ſpecies. Vegetables muſt follow their reſpective natures. Fire, alſo, and the centripetal cauſe, whatever it be, muſt operate according to their reſpective propenſities, or laws of action: and every ſort of active matter muſt purſue the power and *conatus* it received from the Creator, and perform the functions he deſtined it for, without liberty, or ability of change. In all theſe things the actions, the lively operations, and the effects performed, ſtrongly indicate material agents in nature: and the regularity of the effects, with their periodic returns, alſo denote the fixed and invariable laws, according to which thoſe agents operate.

There are therefore in material nature agents, or efficient cauſes, which the Creator has made to ſtimulate and preſerve the motions of this great machine, to carry on the operations of the different parts, and to produce the effects for which thoſe parts were deſtined, according to their places and order. For theſe agents, the Creator has allotted proper ſuſtainment, as far as is neceſſary for their vigour and ſupport: ſo that their action continues, and ſhall uniformly perſevere for the deſtined duration, with, or without his farther attention. This permanence we ſee ſomewhat exemplified even in the works of mechaniſm, which are ſo conſtructed, as to continue their operations for a certain time, whether the artiſt looks to them, or not: however, with this difference, that human contrivances are weak, imperfect, and ſubject to decay; while the works of Omnipotence are perfect and permanent, according to the end deſigned, and the term marked out for their exiſtence.

It was the opinion of the ancients, before aſtronomy was much cultivated, that eclipſes, which they called faintings, or weakneſſes of the ſun or moon, were produced by the immediate agency of the Supreme Being, in order to declare his diſapprobation of certain actions, whether of individuals, or of whole nations. But more modern aſtronomers have found thoſe phænomena to be the reſult of certain permanent laws, according to which the planets move round their orbits, and thus induce aſpects and elongations, conjunctions and oppoſitions; and, conſequently, tranſits and eclipſes: all theſe phænomena are now calculated and foretold by aſtronomers according to certain rules, which could not be inveſtigated, were there not ſettled laws eſtabliſhed in nature. Now we find the operations and productions of nature, as well as the powers and propenſities of her beings, equally ſtated and regular; they have therefore, as well as the celeſtial bodies, certain laws to regulate their motions, and certain cauſes to produce them. Again, as the effects and operations of theſe cauſes are material (*per* 3d propoſition) the cauſes are alſo material, and are thoſe very material agents whoſe neceſſity we have inferred from the wiſdom of the Creator, and whoſe actual exiſtence experience points out.

Theſe material agents, though hitherto undiſcovered, may hereafter be as well known to natural philoſophers, as the orbits of the planets are now to aſtronomers: and thoſe who require an actual agency of God for performing the operations of nature, may hereafter be thought as deficient in philoſophy, as thoſe who formerly imputed eclipſes to a ſupernatural cauſe, at preſent appear to have been in aſtronomy.

What we have ſaid on the ſubject of material agency, is a general refutation of that part of the definition to which we have objected; for once admitting material agents, or certain ſpecies and portions of matter, endowed with a power and invariable propenſity to act, according to a certain law, from the creation to the diſſolution of the world, it neceſſarily follows, that all matter is not inactive or inert; for ſuch ſpecies or portion is really active: conſequently, the definition of matter muſt be corrected, as it ought to contain no properties but ſuch as are common to all matter whatſoever. However, as it is alſo certain that ſome matter is inert, we ſhall now examine this property more particularly, in order to determine by experiment, what body or ſpecies of matter is really inert.

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SECTION II.

Teſt to determine the inertneſs of bodies. No body found inert. Falſe notion of the cauſe and ratio of inertneſs.

INERTNESS of body or matter is an inability therein to change, or alter its condition, ſtate, or figure, be either what it may, until ſome external cauſe or force acts upon it to make the change.

To this definition of inertneſs, we ſhall annex three explanatory caſes, that will prevent confuſion of ideas, and obſcurity of terms; afterwards we ſhall bring body or matter in general to the teſt.

CASE I.

If an inert body be at reſt, it cannot acquire motion of any kind, without the action or force of an external cauſe; or if it be in motion, it cannot, without ſuch a cauſe, come to a ſtate of reſt.

CASE II.

If an inert body has been reduced to a different form or figure, by any external cauſe, or if any impreſſion be made on it, which it had not before, it ſhall not recover its former condition or figure, nor throw off, or deface the impreſſion newly received, without the aid of an extraneous cauſe.

CASE III.

But if the body, by any innate power, reſumes its priſtine figure or condition, or makes any effort to regain it, ſuch body cannot be really inert; and whatſoever be the effort that any natural power therein makes to regain its former condition, or deface the impreſſion lately made, ſo much muſt the body or its parts have of innate power, which is the reverſe of inertneſs.

Now if we try every body or kind of matter in the world, not one ſhall be found to ſtand the teſt of the firſt caſe; for, hold out a ſtone, or any other body in your hand, as if you meant to place it in the air, the inſtant you let it go it ſhall fall to the ground, if it be not ſet to reſt upon ſome other body that will ſupport it: now ſince this body did not remain at reſt in the part of univerſal ſpace you deſigned to place it in, it cannot by the firſt caſe be inert, except the motive force, which made it fall, was from an external cauſe. This motive cauſe is called *gravity;* the queſtion therefore is to determine whether gravity be innate in the body, or not.

If gravity be an innate cauſe in the body, or its parts, whereby its deſcent is thus induced, *per* third caſe, it cannot be really inert, but, on the contrary, it muſt be allowed to have an innate power of action, in proportion to the velocity or force that the power of gravity generates in it when falling.

But if gravity is proved to be a power, or cauſe of motion extraneous to it, the body ſhall, notwithſtanding the velocity or force it gains by the fall, be allowed to be inert, according to the firſt caſe. Conſequently, a a lump of lead, a ſtone, or any other body cannot be allowed to be totally compoſed of inert matter, until gravity is proved to be an extraneous cauſe, and not by any means innate in the body.

Again, perhaps there is not a body in the univerſe which will ſtand the teſt of the ſecond caſe, on account of ſome degree of innate elaſticity: for there is no body of any kind, if bent or preſſed, that will not, when the cauſe of preſſure is removed, make efforts in ſome manner to regain its former figure, or whoſe parts will not operate to recover their former ſtate. Therefore, by the third caſe, ſuch body cannot be perfectly inert, but, on the contrary, has an innate power or action, proportionable to the effort it makes to recover its former ſtate and figure.

Beſides the above caſes, the powers in bodies to excite ſenſations of their various qualities would be a proof of their not being perfectly inert; for without ſome power in a body, how could its odoriferous particles come forth, which, however, are often perceived at a conſiderable diſtance? How could it impart a guſt, or excite a ſound?

That a body ſhall have theſe powers to act, and at the ſame time be ſtiled perfectly inert, that is, void of every kind of power to act, is a plain contradiction in terms; ſuch an idea is inadmiſſible in ſcience and repugnant in nature. I believe it is an acknowledged axiom, at leaſt it has been proved in our firſt lecture, that the ſame ſubſtance cannot have oppoſite eſſences; if ſo, no one ſubſtance, uncompounded part or particle of matter ſhould be endowed with oppoſite eſſences. Therefore, the oppoſite powers and qualities we find in any one body, muſt ariſe from different principles therein, *i. e.* from different ſpecies of matter endowed with their reſpective eſſences. Theſe different ſpecies, when united together, form a compound body endowed with the powers of all; and the different powers a body exhibits, indicate the ſeveral ſpecies of matter that enter into its compoſition; for when theſe powers are oppoſite, or incompatible, each muſt be eſſential to a diſtinct ſubſtance. Thus the matter of fire or flame muſt be different from gravitating matter, being of oppoſite powers and propenſities; and both theſe ſpecies of matter muſt again differ from inert matter, which has no propenſity except that of reſt.

Thus we have in nature three diſtinct ſpecies of matter. The effects of the two former are ſufficiently known by daily experience; the laſt may be inſtanced by the pure white aſhes of paper, which are void of coheſion, elaſticity, ſmell, taſte and all other qualities and powers, except gravity, which if not innate in body, theſe, as well as the ultimate reſiduum of animals and vegetables, when purged of their ſalts, are perfectly inert; for they are deſtitute of all qualities except extenſion, tangibility, &c. without which we cannot have an idea or ſenſation of matter.

It is my opinion that neither gravity nor inertneſs is eſſential to all matter, for two reaſons. Firſt, we can have an idea and be ſenſible of matter, without a notion of either; and ſecondly, light, which we have proved to be matter, ſeems to have neither inertneſs nor gravity, which ſhall be examined hereafter. Conſequently, the 'primordial matter which is ſaid to have been without form, *i. e.* without qualities before the Creator brought light into being, was inert. This alſo may hereafter be farther conſidered: at preſent we ſhall examine the notions of our modern philoſophers with regard to the inertneſs of matter, which we ſhall take from the Philoſophia Britanica. This work has been collected and compiled by a Mr. Martin from the beſt treatiſes, he ſays himſelf, on phyſics now extant.

" *Vis inertiæ,*" ſays this author, vol. 1. page 11. " (as Sir Iſaac Newton called it) or

" the inactivity of matter, is that property of
" it, by which it endeavours to continue in its
" ſtate either of motion or reſt, or by which it
" reſiſts the action and impreſſions of all other
" bodies, which tend to generate, or deſtroy
" motion therein. This power or force of
" matter" (continues he in a note) " ariſes
" wholly from its ſluggiſhneſs or inactivity,
" and not at all from its gravity, as ſome (of
" no ſmall name) have miſtakenly conceived
" of it."

This aſſertion, *viz.* that inertneſs, or the power of reſiſting the generation or deſtruction of motion, proceeds not from gravity, he proves, by ſhewing that a force impreſſ'd in an horizontal direction, produces the ſame effect, or carries a body through the ſame ſpace, in the ſame time, whether gravity acts, or not; ſo that as the ſame force is required to give that horizontal motion in both ſuppoſitions, he concludes, that inertneſs which renders this force neceſſary, doth not depend on gravity, but ariſes ſolely from the nature of inactive matter, and is, on that account ever proportional to the number of particles or quantity of matter in bodies. This proof is certainly ingenious; however, it is not ſatisfactory, nor is the laſt inference drawn from it juſt. In the firſt place, gravity is only removed in ſuppoſition, not in reality; which makes a great difference: for when gravity is only ſuppoſed abſent, the author is at liberty to ſuppoſe that the effect of the horizontal force is the ſame without gravity as with it: but if the effect of gravity was not ſimply ſuppoſed abſent, but by ſome contrivance really removed, then we ſhould find by experiment, without taking it on the word of any author, whether the horizontal force ſhould have the ſame effect with, and without gravity. This we ſhall endeavour to remedy, by contriving methods of removing the effects of gravity, and then trying whether inertneſs, as this author imagines, will vary according to the quantity of matter.

Get two bottles or bubbles of glaſs, very different in magnitude, put ſhot or ſand in each, ſo much as will bring them to the ſpecific gravity of water; now it is evident, they will remain at reſt in any part of a veſſel of water that you place them in, and their gravities will have no effect, the bodies being in equilibrio with the water: ſo that their *vis* *inertiæ* ſhall be the ſole impediment to their motion, except that the fluid will reſiſt their ſmalleſt motions, in the proportion of their ſurfaces, againſt which it reacts.

The bubbles may be ſo different in magnitude, that one will take a pound or two, and the other but an ounce of ſand, to bring them to the ſpecific gravity of water. Both being ſuſpended and at reſt in the ſame depth of water, ſee the different forces or weights neceſſary to ſtir them; each force being noted, and divided by the ſquare of the diameter of its reſpective body (to allow for reſiſtence), if the quotients in both are found to be the ſame, the *vis inertiæ* muſt be the ſame, notwithſtanding their difference in quantity of matter.

The forces to ſtir them in the fluid may be thus accurately determined. Let the bubbles have a wire hook inſerted in correſponding parts, to receive a thread that may be tied to one end of a ballance, at the other end of which let there be a ſcale to receive the weights or grains neceſſary to ſtir the bodies in the water; theſe weights being divided by the ſquares of the diameters of their reſpective bubbles, the reſulting quotients will expreſs the proportion of their *vis inertiæ.* It will be worth while to make this apparatus accurately, not only to determine this queſtion, but others concerning the tenaciouſneſs of different fluids, which ſhall be as the weights that give motion to the ſame body in them, when as above reduced to their reſpective ſpecific gravities. But as it is not eaſy to remove an eſtabliſhed principle, I ſhall add another experiment, which admits of mathematical demonſtration.

Let a box or caniſter, wherein different weights may be put occaſionally, be ſuſpended like a pendulum, at different lengths proportioned to the weights contained; if you allow a foot from the point of ſuſpenſion to the centre of the box, when a pound is in, allow twenty feet for twenty pounds, ſo that the pendulous lengths ſhall be as their weights. Let an hook or wire be inſerted at the central part of the box or caniſter, to which a thread is fixed that will ſtretch horizontally over a very free pulley; and at the other end of this thread let a ſcale be joined, to receive the weights or grains that will draw the box aſide from the vertical line of free ſuſpenſion; then note the weights or grains that will draw the central part of the box, when loaded with each weight, the length of an inch, or even the tenth of an inch from that vertical line, and you have the force of inertneſs in each weight, expreſſed by the grains that move it from that line: for whatſoever moves the body overcomes its *vis inertiæ*.

We learn from the doctrine of inclined planes, that where the length of the plane is the ſame, the force of aſcent or deſcent in the ſame or equal bodies ſhall be as the height, or as the ſine of its angle of elevation. Hence the forces to move the ſame, or equal bodies through arches of equal chords ſhall be as their verſeſines: but if the length of the plane and its height, *i. e.* the chord and its verſeſine are given, the forces of deſcent in different bodies, or the forces to drive them up, will be as their weights. Conſequently, when the verſeſines of equal arches, and the weights of the bodies vary, the forces muſt be in the compound ratio of both; and therefore, when the weights and verſeſines are reciprocal, the forces to move them muſt be equal: and therefore again, if the ſame weights or grains ſtir, *i. e.* overcome the *vis inertiæ* of theſe bodies that have pendulous lengths, ſo proportioned to their weights, or draw them through equal chords of different circles, ſuppoſe but the tenth part of an inch, their *vis inertiæ* muſt be equal.

For we know the chord of an arch is a mean between its verſeſine and the diameter of the circle. Therefore, when equal chords are taken in different circles, the diameters and verſeſines muſt be reciprocal; but the weights are as the diameters, or pendulous lengths, *that is*, inverſely as the verſeſines: therefore, when the bodies are ſuſpended by pendulous lengths that are as their weights, they ſhall be moveable by equal weights, or forces, except their *vis inertiæ* take effect; and whatever that be, ſhall now be expreſſed by the different weights or grains in the ſcale, which are found neceſſary to move theſe different bodies. We ſaid the number of grains to draw the body aſide through equal arches, when ſuſpended by lengths that are as the weights; but in this ſome conſideration muſt be made for a greater reſiſtance, which the longer pendulum meets with, eſpecially if the box is lower where the air is more denſe. Beſides, the greater weight will cauſe a greater friction at the centre-pin, from whence it is ſuſpended: and in the bending of the chord, there is more difficulty when the weight is great. In all experiments, every circumſtance muſt be attended to, otherwiſe the experimentaliſt will fall under the imputation of ignorance, or juglary, which, though not equally cenſurable, equally obſtruct the diſcovery of truth.

Now, when theſe experiments are accurately made, and every circumſtance conſidered, and duly valued; if the difference of forces to ſtir theſe two bodies, one of a pound, and the other of twenty pounds, whoſe difference is nineteen pounds, is found to be but a few grains, which may be occaſioned by the reſiſtance of the air, or ſuch extrinſic cauſes; *vis inertiæ* may be conſidered as the ſame in all bodies, and therefore to be neglected in every computation, being a conſtant invariable quantity in all heavy bodies, great and ſmall, which admits of no various degrees, increment, or force.

SECTION III.

What the term *vis inertiæ* means, how it may be applied, whence the notion took its riſe, and why ſo much inſiſted upon.

THE term *vis inertiæ* ſhould naturally appear highly improper, on account of the apparent contradiction between the words *vis* and *inertiæ*, the union of which nothing could juſtify, but the neceſſity of expreſſing various attachments to reſt in different bodies, proportioned to their quantities of matter, and different from the attachments occaſioned by gravity. This notion has been ſufficiently refuted; ſo that one body is not to be conſidered as more at reſt than another, no more than one perpendicular line can be called more perpendicular than another. If a body be at reſt it is abſolutely ſo, and admits of no degrees more or leſs: in the ſame manner, if a line be perpendicular to another, it cannot be ſuppoſed more or leſs ſo, without deſtroying the idea of perpendicularity.

This term however might, through prejudice or inattention, be reputed juſt. For example, if we attempt to give a motion to a body different from that of gravity, we find it already pre-engaged by a determination towards the earth's centre; and this natural force is every moment making its effort againſt any foreign force that can be applied to it, and muſt be overcome before the body can be moved. Now a philoſopher, who either has not enquired into the true cauſe of this repugnance to motion in the body, or who chooſes to confine himſelf to the effect, will chop the matter ſhort, and call this repugnance *vis inertiæ*, whatever be its cauſe. Thus a mere effect of gravity may at length be conſidered as a force entirely diſtinct from gravity; which error muſt prove of very pernicious conſequence, according as the miſtaken tenet becomes univerſal. But force of reſt in this caſe is juſt as proper, as force of perpendicularity would be, if made uſe of to expreſs the force wherewith a poſt ſtands upright, when fixed in the ground. Another reaſon for annexing the idea of force to inertneſs was, to ſignify ſomething poſitive, preſerving in a moving body the force of impulſe it had firſt received. But this perſeverance of the firſt impulſe, ariſes from the body's having no power to deſtroy that impulſe: ſo that in this caſe, a mere defect of power is called *vis inertiæ*, whereas in the former, that term expreſſed a force which really aroſe from gravity.

It alſo appears, from what has been ſaid, that inertneſs is not an univerſal property common to all matter; except in a ſenſe whereby a fiſh, frog, mouſe, or any other animal, however active, might be ſtiled inert. Theſe vigorous animals might in ſome ſenſe be called inert, in as much as they can neither give themſelves a progreſſive motion, nor ſtop ſuch a motion, when impelled to move, without ſome fluid or ſolid body to work upon. For throw a mouſe, or any other ſmall animal out of your hand, it muſt, like a lump of lead, or a ſtone, go in the ſame direction of the force impreſſed, until its velocity is entirely abated, or until it meets ſome obſtacle to grapple. However, notwithſtanding this inability to move, or ſtop its own motion, it cannot properly be called inert; becauſe it exerts many active powers. Therefore no other matter is to be thought inert, on account of its wanting that power, while it exerts others. Now it is clear, that few or no bodies are ſo void of action or power, as to have no motion in their parts, to emit no effluvia, or to excite no ſenſation: how hard therefore it is to find a body really inert! Aſhes, or the ultimate *reſiduum* of burnt vegetables and animals, purged of their ſalts, if ſuppoſed void of gravity, may be looked upon as perfectly inert, as we ſuppoſe the primordial matter to have been before light got exiſtence, which doubtleſs gave it vigour, warmth and vivacity, and conſequently ſuperinduced on it elaſticity, with a vegetative quality, by reſolving it into diſtinct collections of the homogeneous parts, for the various purpoſes of nature.

This primordial matter, void of qualities, may be repreſented by a miſt or fog, which we ſee ſuſpended in the form of a confuſed, undigeſted, ſtagnant fluid, without action, motion, or qualities, until the ſun ſhines very ſtrongly upon it, whereby it is diſperſed, and its homogeneous parts ſelected and united together for their reſpective purpoſes. Its humid parts coaleſce to water, and ſeparate from the earthy parts, which fall to the ground; the aerial parts thereof being thus depurated, become clear, and of a piece with the atmoſphere. In this fog or miſt, we ſee no ſign of gravity, of levity, of elaſticity, or coheſion. Neither is it characterized by light or darkneſs, heat or cold in the extreme; nor by any other of theſe diſtinct qualities which are ſo obſervable in all other bodies; it is therefore a true repreſentation of the chaotic matter, void of form.

It would not here be an impertinent enquiry to aſk, why the *vis inertiæ* of matter has been rendered ſo univerſal by thoſe very philoſophers, who make the active power of attraction equally general? Or why they are ſo tenacious of that torpid property, which ſeems inconſiſtent with the operations of nature? The *vis inertiæ* of matter, according to theſe philoſophers, implies a ſluggiſh force therein, which reſiſts motion. This reſiſtance, they ſay, is in proportion to the quantity of matter, or to the *vis inertiæ* of what ſtands in the way or paſſage of the moving body; whence we are to underſtand, that where motion is perpetual, there can be no reſiſtance, *i. e.* according to this doctrine, no matter, but a perfect vacuum. Hence we ſee that the *vis inertiæ* of matter ſeems to induce the neceſſity of a vacuum in the planetary ſpaces; that property is therefore the greateſt ſupport of the reigning ſyſtem, and ſhould be obſtinately defended by all who undertake to maintain a vacuum. But this tenet is as contrary to our knowledge and experience in nature, as the inertneſs upon which it is founded, is inconſiſtent with her operations. For the body of an animal is not a vacuum, yet the circulation of its blood and other fluids is conſtant and regular. A vacuum is not neceſſary in the ſea, to facilitate the motions of fiſhes and ſhips; on the contrary, this fluid is to both a vehicle: nor could birds or clouds move in the air, without a correſponding vehicle: ſhould not the planets therefore, according to Newton's ſecond rule of philoſophizing, to wit, that like effects ſhould have like cauſes, have ſome medium, or like vehicle for their motions? Would not ſuch a medium be more analogous to the other works and motions of nature; and alſo more conſiſtent with Infinite Power and Wiſdom, than a vacuum? If philoſophers can thus depart from analogy, by what means ſhall they come to the knowledge of things that are beyond the reach of their ſenſes and experience? By what rules ſhall they erect a ſyſtem of phyſics? If analogy, grounded on experience, is not attended to, according to that fourth rule which Newton eſtabliſhed in order to exclude concluſions ariſing from hypotheſes, and to admit none but thoſe founded on experiment, their ſyſtems muſt be in a great meaſure ideal or imaginary. Doubtleſs then the neceſſity muſt have been unſurmountably great, which has thus obliged them to ſtep aſide from the known courſe of nature; and to depart ſo far from the ſcientific train of analogy, as to loſe ſight of the principles and vehicles of motion they had, and have in conſtant and univerſal experience.

This neceſſity ſeems to have proceeded from the admiſſion of ſome principle, which is probably as erroneous, as its conſequences are falſe. This principle can be no other than gravity, which is held forth as the *primum mobile* of nature, or the chief agent which carries on and preſerves the planetary motions. Gravity is defined the power and force, &c. by which bodies near the earth tend to its centre, and planets to the ſun. Some ſay it is an univerſal property of matter, but Newton declares he does not take it for an eſſential property. Some perſons will have it peculiar to matter, and yet make it act with full force in vacuo; almoſt all agree in making it the cauſe of nature's operations; yet no one has determined its particular reſidence, adequate ſubſtance, or peculiar eſſence; but when they are urged for its particular nature and reſidence, they give the univerſal ſalvo, to wit, that God made it, that, according to his divine ordinance, it obtains in nature, and is the cauſe of her motions. Thus, contrary to our axioms, which were deduced from principles grounded on the works of the Omnipotent Creator, and which are quite conformable to his infinite wiſdom; material effects and operations are admitted without a material cauſe or agent, a power without an adequate principle, and an eſſence without its proper ſubſtance.

In ſhort, ſince philoſophers attribute neither eſſence, ſubſtance, nor any thing material to the action of gravity; ſince they make this power act in ſpaces void of any material fluid to cauſe or exert it; they muſt mean that it is an immaterial power exerted by diſtant matter. This is the only conception which can give any conſiſtency to their other opinions; for the planets being actuated by gravity, which is immaterial, may move in vacuo; whereas if they were actuated by a material power, the ſpaces they move in could not be a vacuum, as containing the material ſubſtance exerting that material power.

Thus *vis inertiæ* introduces a vacuum; and to preſerve this vacuum, the cauſe, which produces motion therein, muſt be an immaterial one, the idea of which is ſubtly conveyed by the ambiguous term *attraction*. But as hypotheſes have been long ſince exploded, no phyſical principles ſhould now be admitted, but ſuch as are conformable to the ſimplicity of mechaniſm, whereby an All-wiſe Being muſt be ſuppoſed to govern the world; and even ſuch principles and faculties as are proved to exiſt in thoſe parts of matter ſubject to experiment, if by experiment alſo they are found confined to matter of a certain nature, while bodies of another kind are obſerved totally exempt from them, in this caſe, I ſay, they are not to be called univerſal properties of all bodies. Neither are mathematical calculations, however ingenious, to be looked upon as a confirmation of a phyſical ſyſtem, or as reſponſible proofs of the actual being of the agents ſuppoſed: becauſe mathematics only compute and aſcertain the ratio and proportion of the forces ſuppoſed; but never indicate the nature or cauſe of thoſe forces; it being very eaſy to adjuſt ratios on falſe principles. As for inſtance, let a centripetal force act in a certain ratio, if once the law of this force be diſcovered, its effects may be truly calculated by mathematics, without knowing or determining, whether this centripetal force be attractive, or compreſſive. This Newton himſelf acknowledges. "What I call attraction," ſays he, "may be performed by impulſe, or by ſome "other means unknown to me." Further, that mathematical calculations may be juſt, though grounded on falſe ſuppoſitions, is ſtrongly exemplified in the Ptolemaic ſyſtem, which is confeſſedly contrary to nature; nevertheleſs, in this ſyſtem tranſits and eclipſes were foretold, the riſing and ſetting of the ſun and ſtars adjuſted, and all phænomena ſo calculated and explained, as to render it apparently indubitable.

After theſe obſervations on the inertneſs of matter, it is natural to go in ſearch of thoſe active powers, which have been remarked to ſubſiſt in all bodies, ſuch as elaſticity and gravity, and to examine whether theſe powers be univerſal in body, or belong to particular kinds of matter: and if the latter be the caſe, to aſcertain the ſpecies of matter to which each belongs. However, as gravity is very obſcure, we ſhall for the preſent confine ourſelves to elaſticity and its cauſe. This ſhall be the ſubject of the following Lectures; in the courſe of our reſearches, ſome viſto may open to conduct us to the nature and cauſe of gravity.

LECTURE III.

On the Elaſticity of Bodies.

SECTION I.

An elaſtic Principle in Vegetable, Animal and Foſſil Bodies, with Remarks thereon.

ELASTICITY is that reſtorative power in body, whereby it regains, or endeavours to regain its former figure; or whereby the parts of a body preſſed make effort to recover their places and former ſtate, when the preſſure is removed. In the preceding lecture we have ſeen, that a body perfectly inert would not only be incapable of producing or deſtroying motion in itſelf, but even of reſuming its former figure, if bent or preſſed: and we may now add, that if inertneſs were an univerſal property common to all matter, ſenſation could no longer be excited according to that natural mechaniſm, which philoſophers ſo much admire. For external objects, being totally inert, could have no power of acting on our organs by their own ſubſtance; nor could any intervening medium exert that action; for this alſo, being material, would neceſſarily be inert. Thus, ſenſation not being excited by material agency, nor having any connexion with body, the ingenious Berkley might have drawn from this ſuppoſed inertneſs a forcible argument to impugn the exiſtence of bodies. But though inertneſs was not productive of ſuch abſurdity, no philoſopher ſhould ſuppoſe, or allow it to be univerſal. A body is not to be called inert on account of its being incapable of moving itſelf, or ſtopping its own motion, if it contains an active principle, which enables it to excite ſenſations, to effuſe its qualities, to unbend itſelf, or to recover its ſtate; for in as much as it is endowed with ſuch an active or elaſtic principle, in ſo much does it exclude inertneſs. Now as the powers, wherewith matter is endowed, diſcover clearly ſome active principle; to explore, aſcertain, and define it, ſhall be the purport of the following treatiſe.

The uſe of the bow proceeds from its elaſticity. The invention was obvious from bending the branch of a tree, which being let go again, will immediately ſpring into its natural poſition. The ſtem of a plant, or flower will do the ſame, though not with ſuch force; but any reſtorative act, however weak, is a proof of elaſticity: therefore, all kinds of growing, or freſh vegetables, are in ſome degree elaſtic. Wool, hair and feathers are alſo evidently elaſtic; for, like vegetables, they have a reſtorative power, whereby they recover the form of their growth, when the cauſe of reſtraint is removed: now to recover their former ſtate, or make any effort thereto, is the teſt of an elaſtic principle. In like manner, if the fleſh of any animal, recently killed, be preſſed with the finger, the indented part ſhall, on the removal of the finger, recover its former ſtate. The parts of a living animal will reſtore themſelves ſtill more vigorouſly; and it ſeems, that this elaſtic principle in fleſh becomes weaker, according to the time the animal is dead: for when it begins to acquire a bad ſmell, an indentment will remain; or if the putrifying fleſh has any reſtorative power, its effects are ſlow and languid, and the more ſo, the nearer it approaches to putrifaction; ſo that, at length, its elaſticity, nutrimental qualities and all other powers are loſt, and ſeem to have been carried off by the rancid effluvia that effuſed from the body while diſſolving. At length it is entirely reduced to pure inert matter, which is void of coheſion, elaſticity, ſmell, taſte, and all the other lively qualities the original body poſſeſſed. This inſtance leads us to think, that whatever is the cauſe of elaſticity in animals and vegetables, the ſame alſo is the ſource of their other lively powers and qualities; for theſe powers come and go with elaſticity, and ſeem not only concomitant, but alſo connected with it.

Anatomiſts, and all thoſe who handle and make experiments on the inteſtine parts of animals agree, that they are all elaſtic, which is immediately evident from the perſpiration of an animal, from the ſpring of its blood, when a vein is opened, and from its power in excluding urine and excrement. Theſe effects and operations muſt have an adequate cauſe. Anatomiſts ſpeak of a periſtaltic motion, but I mean, the cauſe of that motion; wherefore, there certainly is an expanſive principle in the animal, which operates to all ſides at once, as if it were from a centre, with elaſtic force, which is the cauſe, and *primum mobile* of all its motions, and of the circulation of its blood. The activity and ſtrength of an animal likewiſe depend on the elaſticity of its muſcles and other parts.

Having, then, aſcertained a principle of elaſticity in all kinds of vegetable and animal bodies, we ſhall now examine, whether this property be common to foſſils; for which purpoſe we ſhall firſt aſſign a teſt, or ſtandard to judge by. We have ſeen that a ball of wool, hair, or feathers, will, by the elaſtic ſpring of its parts, recover its figure and former convexity, the indented parts riſing to their places, as ſoon as the cauſe of preſſure is removed: and the harder one of theſe balls is made, the more vigorouſly will its elaſticity be exerted. Now if one of theſe balls be let fall on a flag, it will immediately rebound; and the ſtronger the ſtroke, the more vigorous will be the rebound; whereas, when the preſſure is ſlight, the reſtoration is proportionably weak and ſlow: from which inſtance, and from common experience it appears, that the reſtitutive act has ſuch a relation to the act of preſſure, that both are alike forcible, or nearly ſo.

Now let two ſuch balls be ſuſpended by two threads of equal length, from two pins ſo ſituated, that when they hang freely, they ſhall touch in a point exactly between their centres, ſo that a line drawn through the two centres and the point of contact, ſhall be parallel to the horizon. Then let a perſon take one of theſe balls ſo ſuſpended in each hand to a ſmall height, as if to deſcribe equal arches in the ſame vertical plane; on letting both fall at the ſame inſtant (that they may meet in the ſame vertical line of free ſuſpenſion, in which they firſt hung) they ſhall ſtrike together, each having a force according to its weight and the velocity it acquired with the ſweep of its fall; and after the ſtroke they ſhall rebound to ſome height along the ſame arch through which they fell.

Their rebounding or receding thus from each other after the ſtroke, is a proof they are endowed with an elaſtic principle in ſome degree; for the touching parts being preſſed in by the force of colliſion, it was their reſtorative forces, then reacting againſt each other, that threw the balls aſunder: ſo that when the force, wherewith the preſſed parts recover their places, is great, it ſhall perhaps throw them to the height from whence they have fallen; when it is weaker, it ſhall throw them to a ſmaller height; but if they have no reſtorative power, the preſſed parts will not riſe, or react, ſo as to ſeparate the balls after the ſtroke. In this caſe, they are ſaid to be non-elaſtic; and, in this caſe, we pronounce them inert, unleſs they have power to excite the ſenſation of ſuch ſenſible qualities as argue a motion in the body's parts. For as to gravity we conceive that it is not eſſential to all matter; wherefore the body that is void of elaſticity, and gives no ſenſation of ſmell, taſte, or ſound, no matter how heavy it be, may be looked upon as compoſed of inert matter. However we muſt leave our opinion relative to gravity open to correction, until the point is determined in the concluſion of our treatiſe on that ſubject.

Hence, whatever two bodies of the ſame kind or ſpecific nature are thus ſuſpended, and thus let fall againſt each other, ſo as to ſtrike if they have any degree of elaſticity, ſhall ſeparate after the ſtroke; and converſely, any bodies of the ſame ſpecies thus ſuſpended and tried, if they are found to rebound or ſeparate after the ſtroke, muſt have ſome degree of elaſticity; becauſe their ſeparation muſt ariſe from a repulſive power, of the parts that are preſſed by the ſtroke: for if theſe parts had no repulſive power they could not repel, and therefore could not make the bodies ſeparate after the ſtroke; which is the teſt of inertneſs, or of the want of an elaſtic principle. Moreover, whatever effort the preſſed parts make to recover their ſtate, will be expreſſed by the diſtance of their ſeparation after the ſtroke, or the height to which they riſe: and this we ſhall call the *pendulous teſt*, to determine the elaſticity of foſſils, &c.

Yet this cannot be a juſt criterion, unleſs the pins, from which the balls are ſuſpended, are at a diſtance equal to the ſum of the ſemi-diameters of both the balls, ſo that in hanging freely they but juſt touch; and then the ſuſpending threads ſhall be parallel. Secondly, their centres muſt be in the ſame horizontal line, that the forces of concuſſion may not be oblique. Thirdly, two bodies of the ſame ſpecies of matter, and equal in magnitude, muſt be brought to this teſt together; and the reſult of this teſt ſhall determine the degree of elaſticity in that kind of matter. Perhaps a table of the ſpecific elaſticity of bodies may prove no leſs uſeful in phyſics, or in the concerns of life, than a table of their ſpecific gravities. The reaſon we object to the bringing of two bodies of different kinds to this teſt is, becauſe the reſtorative power of the elaſtic body would affect the non-elaſtic as much as it does itſelf, for in ſo much as it is the lively agent of reaction on itſelf, it is that of action on the other, wherefore both would recede equally from each other, and thus both would ſeem equally elaſtic.

Now we ſhall ſhew how by this pendulous teſt, a table of the ſpecific elaſticity of bodies may be raiſed, for it may hereafter prove very uſeful to compare the ſpecific elaſticity of bodies with their ſpecific gravity. It is the received opinion, that a body is *perfectly* elaſtic, when the *reſtitutive* power of the parts is equal to that wherewith they are preſſed; and it is therefore ſaid that balls, or bodies that are perfectly elaſtic (if equal, and ſuſpended in the manner we have directed) being let fall from the ſame height, ſhall, after the ſtroke, reaſcend to that height again. It muſt alſo be remarked, that the velocity acquired by a pendulous body in falling through an arch of a circle, ſhall be as the chord of that arch; which is learned from the theory of inclined planes, and the motion of a circular pendulum; and that the height to which a body riſes, or from which it falls, is meaſured by the chord of the arch it deſcribes: therefore if theſe bodies riſe to the ſame height from whence they have fallen, the velocity up and down being the ſame, and the bodies the ſame, the forces up and down muſt be the ſame. In which caſe, the reſtorative power, or force of reſtitution is equal to the force of the preſſure; therefore, when ſtriking bodies riſe to the ſame height after the ſtroke, from whence they fell before it, they are ſaid to be perfectly elaſtic, according to the common acceptation of perfect elaſticity.

Of all the bodies that have been thus experimented upon, the elaſticity of ivory balls comes neareſt to this perfection; becauſe the arch through which they riſe after the ſtroke, wants but a little of that through which they fall: and as no body is found that will riſe to the full height, it is preſumed there is not a body in nature perfectly elaſtic. Now to find the degree of elaſticity in ivory, or in any other body, let two of the ſame ſpecies be made equal and ſpherical; and being ſuſpended in the manner above directed, let each fall from an arch of ſixty degrees, whoſe chord ſhall therefore be equal to the pendulous length. All bodies let fall from this height will acquire equal velocities in their deſcent through this arch; conſequently the two bodies let fall together, being of the ſame weight, will ſtrike together with equal forces; their reſtorative powers ſhall therefore be expreſſed by the velocities generated after the ſtroke: for the reſtorative powers are the ſole cauſe of the ſubſequent motion. Now theſe velocities, and conſequently the reſtorative power which gives riſe to them, are meaſured by the chords of the arches, which the bodies deſcribe in their aſcent after the ſtroke. For the quantities of matter being the ſame, the forces will be as the velocities, *i. e.* as the chords in aſcent.

A table may therefore be obtained of the ſpecific elaſticity of all coheſive bodies, which can be made ſpherical, ſuch as metals, glaſs, ſtones, and many other foſſils; alſo wood of every kind, bone, horn, ivory, &c. This table may be made from the lengths of the chords, or the degrees and minutes of the arches deſcribed; it might alſo be made from the verſeſines of thoſe arches; but as the arches are the largeſt ſcale, and their degrees moſt in uſe, they deſerve the preference.

To prevent reſtraint, we ſhould obſerve that it is not neceſſary, according to this theory, to make any bodies of equal weight, except the two of the ſame kind of matter, which are together brought to the teſt; but all the bodies thus tried muſt be let fall from one and the ſame height, *viz.* from the ſummit of an arch, whoſe chord is equal to the length of the pendulum. Wherefore the pendulous length may be a foot, a yard, or any length at pleaſure; becauſe the arch of ſixty degrees being common to all, will give to all the ſame propenſity ariſing from gravity.

Any other given arch might be the common ſtandard, but this is moſt commodious, becauſe its chord is equal to radius, and it will afford ſcope and variety enough to anſwer all degrees of elaſticity. In falling from this common height, all bodies, be they light, or heavy, have the ſame velocity; and the height in aſcending gives the velocity generated by the reſtorative force; which gives the degree or proportion of the elaſticity in the ſcale of that common ſtandard, whether the bodies now tried have, or have not the ſame weight with thoſe that were tried before.

Of all metals copper is ſaid to be the moſt elaſtic, for which reaſon it, or braſs that is made thereof, are moſtly uſed for ſounding inſtruments, as drums and trumpets. Copper is often uſed as well as ivory to illuſtrate, by experiment, the theory of elaſtic bodies, after the manner of the pendulous teſt, which we have juſt explained. It may be uſeful to remark, that copper, when in fuſion, is diſcovered, by ſad experience, to have a moſt expanſive faculty; a drop of water, at that time, having the ſame effect on it, which a ſpark of fire has upon gunpowder; for a drop falling into the furnace will make it burſt forth with prodigious violence, whereby all things around are deſtroyed; or if a mould wherein it is caſt has the leaſt moiſture, it will break forth in like manner.

Again, on the other hand, lead is ſaid to have the leaſt degree of elaſticity, for which reaſon balls of lead, as well as balls of putty, are uſed in experiments to explain the theory of bodies non-elaſtic; yet both theſe ſubſtances ſhew a degree of elaſticity, by ſeparating after the ſtroke in the pendulous teſt we have mentioned, which all philoſophers allow to be a juſt criterion. Wherefore, as no body can be found that will not thus rebound in ſome degree after the ſtroke, it is agreed that there is not a body in nature perfectly non-elaſtic: conſequently, whatever be the cauſe or principle of elaſticity, it is found in all hard bodies.

Before we enter upon the elaſticity of fluids, we ſhall aſſign another ſtandard whereby the elaſticity of hard bodies may be determined, not far inferior to the pendulous teſt above explained. If any ſpherical body be let fall upon a flag, it will immediately rebound to a certain height; and the various heights to which ſuch bodies riſe, in reſpect to that from whence they fall, will expreſs their ſeveral degrees of elaſticity. When a body thus let fall, riſes to the ſame height from whence it fell, it is ſaid to be perfectly elaſtic; becauſe in this caſe the reſtitutive power, which is the only cauſe of the body's aſcent, is equal to the force impreſſed: conſequently, when a body is perfectly elaſtic, we muſt conclude, that the force of its elaſticity is equal to the force of its gravity, ſo that the former increaſes by percuſſion, as the latter increaſes by the body's falling from greater heights. Therefore, when a body is perfectly elaſtic, whatever be the meaſure of its gravity in falling from different heights, will indicate the meaſure of its elaſticity, or of the reſtorative force by which it riſes to the ſame height again.

Now as the force, wherewith different bodies fall from the ſame height, is as their gravities, the heights to which they riſe will expreſs their elaſticities, the force of this power being as the ſquare roots of the heights to which they riſe reſpectively. For the ſame reaſon, the elaſticity of bodies may be meaſured by the heights to which they throw a given weight. For inſtance, the degree of elaſticity in a ſpring, may be diſcovered by letting a bullet, or any other inert body fall upon it, when ſo diſpoſed as to make the falling body rebound perpendicularly; if it throws the weight to the ſame height, from which it has been let to fall, it may, according to the received opinion, be ſtiled perfectly elaſtic. What then ſhall we ſay of the elaſticity of gunpowder-flame, which will throw a body ſeveral hundred times higher than the moſt elaſtic ſpring hitherto invented, and with a force and velocity ſtill more worthy of admiration? Surely this elaſticity far exceeds the perfect elaſticity defined by philoſophers. Is it not therefore erroneous to aſſert, that there is not in nature a body perfectly elaſtic, or to ſet ſuch narrow limits to this ſurpriſing property of matter?

We have in this ſection aſcertained elaſticity in all vegetable, animal, and foſſil bodies whatſoever, eſpecially thoſe which can be brought to the pendulous teſt, we may therefore pronounce, that this property is inherent in ſome degree in all hard and ſoft bodies univerſally.

SECTION II.

An elaſtic Principle in Fire, and in Air.

THE obſervations and experiments we have hitherto made have been confined to ſolid bodies; we ſhall now trace the ſame property of elaſticity through fluids, beginning with fire, the moſt ſubtile and active of all. Doctor Boerhaave ſhews from experiment, univerſal obſervation, and conſtant experience, in his hiſtory of fire, that there is not a body or ſpace in nature void of fire. This point he proves with ſo much perſpicuity and ſtrength, that the world might be imagined every inſtant expoſed to a general conflagration. In the courſe of his laborious inveſtigations, (which ſhew that he paid the ſtricteſt attention to the nature and properties of that powerful agent) he exhibits heat without light, and light without heat, which are both ſenſible qualities of fire; but he depends upon neither as an infallible teſt of its preſence: to judge of this, he makes expanſion the only criterion; becauſe fire ſometimes ſubſiſts without light, and even without a ſenſible heat, but never without expanſion. Expanſion therefore, according to Boerhaave, ſeems to be the eſſence of fire; for he ſays that all bodies whatever, ſolid or fluid, hard or ſoft, light or heavy, will, upon the application of fire, ſwell, rarify, and acquire an increaſe of magnitude and dimenſions, without any alteration in their weight. This law is conſtant and univerſal, but admits of this variety, *viz.* That in the ſame heat, fluid bodies ſuffer a greater degree of expanſion than the hard and ſolid, and lighter bodies greater than heavier. With regard to which, he educes this univerſal rule, that the dilatation of ſolids, by the ſame degree of fire, is in a reciprocal proportion of their reſpective denſities.

Further, the doctor finds that bodies of the ſame ſpecific nature, as for inſtance, glaſs made in England, Bohemia, and Holland, do, by the ſame degree of heat, differ in their degrees of expanſion; he remarks that the body which requires a greater force to melt it, will be leſs expanded, and that the pendulum of a clock will by heat increaſe in length ſo as to take up a longer time in performing its oſcillations: wherefore thoſe which meaſure time exactly in Europe, will become too ſlow in the torrid zone, and too ſwift in the frigid; for they alſo ſhorten by extreme cold. Theſe diſcoveries were made by French mathematicians ſent to both places in order to meaſure a degree of the meridian. That the hardeſt bodies expand by heat, Boerhaave thus proves; having got two rods of iron, made of the ſame dimenſions, and conſequently of the ſame length, one of them being heated becomes ſenſibly longer than the other, and alſo thicker, for when hot it ſhall not enter the ring through which it would paſs when cold; the hotter it is made, the more it is expanded, and ſo its dimenſions continue to increaſe, until it is melted. But when iron or any other metal is put in fuſion, and becomes a fluid maſs, no action of fire ſhall increaſe its dimenſions farther.

Hence it appears, he ſays, that fire, as it increaſes from the greateſt degree of known cold to the moſt intenſe heat, muſt neceſſarily dilate the parts of the hardeſt body to which it is applied, and conſequently move all the particles of the hardeſt maſs, both externally and internally, towards every point of its ſurface, as if its corpuſcles, or very elements were expanded: whence he educes the reaſon why the particles of metals in fuſion, are intimately blended together; for it is known, he ſays, that if a grain of gold be mixed with an hundred thouſand grains of ſilver, the ſmalleſt portion of this compound, taken at any part, ſhall contain its gold and ſilver in the proportion of 1 to 100,000; which experiment alſo proves that fire acts upon gold from its coldeſt ſtate to its moſt intenſe heat, by expanding its dimenſions, and agitating its parts, until its coheſion is entirely deſtroyed: and though the particles may touch, they cannot cohere, while the fire exerts its force upon them; but the fire being removed, they preſently unite in one ſolid maſs.

Without taking down ſo many obſervations and concluſions of this author, we might have ſhewn that expanſion is the eſſence, or as the learned and profound philoſopher Bacon calls it, the *form* of fire; for without this expanſive nature, fire would be uſeleſs; without ſuch a centrifugal and propelling force, it could not ſend forth its heat to warm and cheriſh the ſurrounding bodies, or to qualify and counteract the extreme cold of winter.

The mode of operation, or innate propenſity of this expanſive faculty peculiar to fire, is clearly illuſtrated by the exploſive power of gunpowder when duly placed to blaſt a rock, which is thereby ſhivered to pieces; for the fragments are driven off by a centrifugal propulſion of the ſpecies in the centre, from whence it expands with violence in all directions. The expanſive power and elaſtic ſpring of this flame are beyond deſcription; for, though we may compute the force of gravity in the rock, and its ſuppoſed *vis inertiæ*, how ſhall we contrive to meaſure the force of its coheſion? However, all theſe taken together, are not equal to the expanſive force of that flame, for as they yield, they are inferior to it, and therefore inſufficient to meaſure it. And here it is worthy of admiration to obſerve, that the natural power of expanſion or elaſticity, which philoſophers ſeldom attend to in the ſolution of phænomena, triumphs over the natural powers (if ſuch they are to be called) of gravity, attraction, and *vis inertiæ*, which are continually held forth as the cauſes of all phænomena, and in ſome meaſure as the ſole *principles* of nature.

This expanſive mode of operation is evident from the ſpherical form wherewith a ſingle grain, or even a large heap of gunpowder burſts forth when fired; or by the glowing ſparks which iſſue from very hot iron, or from fiery fuſed metals. It is alſo with ſuch centrifugal propenſity, that heat iſſues forth on all ſides from a fire, and light from the flame of a candle, or from the ſun, being propelled by an elaſtic agency proper thereto, and driven out, as it were, from a centre, with a prodigious velocity in all directions to vaſt diſtances. Wherefore, the intenſeneſs of heat or light, and the propelling force of this elaſtic principle upon any body, muſt be inverſely as the ſquare of the diſtance from the agent of theſe powers.

The elaſticity of light, ſimply conſidered, muſt be prodigiouſly great, ſince this fluid is ſo reflexible as to be ſent back to us from the remoteſt planets in our ſyſtem. Sir Iſaac Newton was of opinion, that ſome power or effluvium emanates from opaque bodies, the poliſhed ones eſpecially, which reflects the light before it actually touches theſe bodies: the ſame he obſerves of the glaſſes of a teleſcope, which prevents their actual contact, when laid on each other, except they are preſſed together. Theſe emanations muſt ariſe from ſome expanſive or elaſtic principle in thoſe bodies, and not from the *inertia* of their matter. The odours of flowers, plants, and aromatic ſpices alſo indicate ſome ſuch expanſive principle in them, whereby their agreeable ſpecies is ſent forth: for ſuch a principle is more neceſſary for the emiſſion of this odorific matter, and other qualities, than in glaſs, white bodies, or poliſhed marble, for the reflection of light. Since, however, minute and accurate experiments diſcover an expanſive principle, in ſome degree, in thoſe hard and heavy bodies, certainly fire and flame ſhould almoſt entirely conſiſt of it; for there is not a body in nature which fire will not ſplit, conſume, diſſolve, or expand by the powerful operation of its elaſtic principle. Light is no leſs powerful, if we conſider its effects in the focus of a burning glaſs, although in open ſpace it diſcovers no other power but that of illumination. Gunpowder likewiſe will exert no conſiderable force, unleſs confined as in the chamber of a mine, or piece of ordnance; but when thus reſtrained, its expanſive power is prodigious; and perhaps that of common fire would not be leſs aſtoniſhing, could it be in the ſame manner confined.

To conclude then, we ſee as well from the notes and obſervations of the induſtrious Boerhaave (whom we have deſervedly followed on this ſubject) as from our own obſervations, that the principle of elaſticity not only exiſts in fire, and is inſeparable from it, but is its very eſſence. We have already traced it through ſolid bodies, and ſhewn that it is common to animals, vegetables, and foſſils; two fluids only now remain, to wit, air and water, in which if elaſticity be diſcovered it muſt be allowed to be an univerſal *principle* in material nature. The authority of Boerhaave might indeed exempt us from the remaining part of this reſearch; but the ſatisfaction which attends ſeeing things with our own eyes, will be an ample compenſation for the trouble of diſcuſſion.

Take a lank bladder, and having bound its orifice ſo tight that no air can get in or out, place it under a receiver, which being exhauſted, the bladder will ſwell to its full extent, as if it were blown up with introduced air. This experiment ſhews the expanſive power of air; for the preſſure of the atmoſphere being removed, by exhauſting the receiver, the little air that remains incloſed in the bladder, being freed from compreſſion, exerts its natural propenſity to expand, by a repulſive power acting from the centre in all directions, as we have already inſtanced in fire, and gunpowder-flame. Hence we may infer, that every part or body of air, be it ſmall or great, is endowed with a faculty of enlarging its dimenſions, or an innate power and propenſity to rarify itſelf. Sir Iſaac Newton ſays in his 31ſt query, that in the production of air and vapour, the particles, when ſhaken off from bodies beyond the reach of attraction, recede from them, and from each other, to above a million times a greater diſtance than they were at from each other, when in the body. This vaſt contraction and expanſion is not intelligible by feigning the particles of air to be ſpringy and ramous, or rolled up like hoops, or by any other means, unleſs they are endowed with a repulſive power; which power is ſtill more conſpicuous in the uſe of the air pump, and the mode of exhauſting the receiver, as being the principle and chief cauſe of that operation.

For an air pump being applied, every operation of the piſton carries off a part of the air contained in the receiver, not by any power in the piſton to lay hold on, to attract, or draw off that part; but it is excluded by the expanſive power of what remains within; and thus, by the ſucceſſive operations of the piſton, the contained air is vaſtly diminiſhed in quantity, and conſequently is vaſtly rarified. But the whole of it never can be carried off; becauſe ſome muſt ever remain to force out, by its expanſive power, what has been excluded; wherefore no veſſel, nor receiver, can ever be perfectly exhauſted of its air by a pneumatic engine.

Hence whatever quantity of air is confined within any veſſel, or circumſcribed ſpace, is equally denſe or rare at all parts; ſo that all parts act and preſs equally on each other throughout that whole ſpace: conſequently, the expanſion of the confined air will ever induce a preſſure of its parts, according to their action upon each other, that is, in the proportion of its denſity. Again, experimentaliſts find, by help of the barometer, that the preſſure of air on the ſurface of the earth is about 15 or 16 pounds weight for every ſquare inch. Conſequently every part of the ſurface of an animal body, may be conſidered as equally acted upon by the preſſure of the ambient air, and therefore the external preſſure upon every animal, is at the rate of 15 or 16 pounds weight, for every ſquare inch round its body. Conſequently, ſome are preſſed inwardly with a force on all ſides, equal to ſeveral tons weight, ſome with hundreds, and the ſmalleſt inſects, even midges, with the force of ounces. Now to form a counterpoiſe, that will preſerve the tone and harmony of the parts, the expanſive power in the internal parts of the animal, muſt be equal to this preſſure; therefore the expanſive force acting from within muſt be at the rate of 15 or 16 pounds for every inch ſurface round its body.

Doctor Goldſmith deſcribes the appearance and ſufferings of a carp, in a large vaſe of water, under an exhauſted receiver, to this purpoſe. "During the operation, a number of "bubbles are ſeen ſtanding on the fiſh's bo-"dy; ſoon after, the animal will appear to

“ breathe ſwifter, and with greater difficulty:
“ it will then be ſeen to riſe towards the ſur-
“ face to get more air, the bubbles on its
“ ſurface begin to diſappear, the belly, that
“ was before ſwollen, will then fall of a ſud-
“ den, and the animal ſinks expiring and
“ convulſed to the bottom.”

Thus all animals perſpire, ſwell, void froth, and expire in convulſions, under an exhauſted receiver; which proves, that their fleſh, fluids, and inteſtines are endowed with an elaſtic or expanſive principle, which operates when the exterior preſſure is removed. The torture of the animal likewiſe ſhews, that its health, eaſe, and life, depend on the equilibrium of its powers, and the equal preſſure on its parts: and if the animal, after this kind of death, was diſſected and duly examined, it might be diſcovered, that the heart and ſome of the inteſtines, or noble parts were lacerated, or at leaſt their texture diſcompoſed: for the falling of the carp’s belly indicates an eſcape of the expanſive principle which ſwelled it before, and which, in that exploſive eſcape, muſt naturally have deranged the parts: and this diſtortion of the parts, might be a more ſudden and certain cauſe of its death, than the want of air for reſpiration, which may be judged of thus. Get two animals, of the ſame kind, for inſtance, two mice, let one die under the receiver, and the other be drowned; then ſee are they equally recoverable in the ſame length of time after death. Drowned animals are frequently revived; but it is my opinion, that any animal, whoſe belly falls in the exhauſted receiver, after it has been ſo ſwollen, ſhall never recover, though not perfectly dead when taken out, the tone of the parts having been deſtroyed by the forcible exertions, or eſcape of the elaſtic matter which they contain, and wherein conſiſted their ſpring and vigour.

Theſe obſervations may illuſtrate the baneful power of arſenic and other poiſons, whoſe active part or very elaſtic ſpecies, when ſet at liberty, is more expanſive than that of animal bodies. The poiſon therefore being diſſolved in the ſtomach, lungs, heart, or veins, and ſtimulated to action by heat, as gunpowder is by fire, burſts and deranges the containing parts, and occaſions certain death. The ſymptoms confirm this explanation; for the expanſion of the poiſon being greater than that of the animal ſubſtances, ſhould naturally produce the ſwelling of the body, the vomiting and convulſions which attend this wretched ſtate.

We have in our way fallen into this propoſition, to wit, the expanſion of confined air will ever induce a preſſure of its parts, according to their action upon each other, that is, in the proportion of its denſity; the truth of which ſeems evident from the experiments we have mentioned; there are many others which might be adduced, as a further confirmation, but we ſhall omit them, and only add a few words in the theory, that may thence ariſe. If we aſſume any given quantity of air, its denſity ſhall be as the preſſure of its parts upon each other, that is, as its compreſſion; and therefore the ſmaller ſpace it is compreſſed to, the greater its denſity, and conſequently the more forcible is its power of expanſion or elaſticity. Therefore, when the quantity and temperature of the air is the ſame, its elaſticity ſhall be as its denſity; which will be as the compreſſive force, and this ſhall be inverſely as its bulk; whence may ariſe the invention of tubes, which with the help of quickſilver, will bring theſe concluſions to the teſt. For, if a certain weight of mercury reduces air confined in a certain ſpace to a certain bulk, double that weight will reduce it to half that bulk. Again, when the ſpace or chamber wherein air is confined remains the ſame, its expanſive force ſhall be as the quantity compreſſed in that ſpace, and hence the invention of the air gun.

There are experiments which prove that heat increaſes the elaſticity of air. Whether this is performed by adding more of the elaſtic ſpecies, or by invigorating that which the air originally contained, we ſhall not here determine; but certain it is, that heat enlarges its dimenſions, as is evident from the uſe of the thermometer, ſo that we may conclude, on the whole, that the expanſive force of air is in the compound ratio of its quantity and heat, and the inverſe of its magnitude: whence the invention and uſe of ſteam engines.

The elaſticity of air is alſo evident from the propagation of ſound. Experiments prove that ſound depends on air, as well as on the vibratory power of the ſounding body: for the ringing of a bell is not heard in a receiver when exhauſted, but clearly when full of air; and even admitting air, without a bell or the like, there will be no ſound: conſequently, ſound depends on both conjointly. All philoſophers agree, that the tremours of the ſounding body are communicated to the circumambient air that touches it, from whence theſe tremours are propagated through the air in all directions, in the form of ſpherical ſhells, after the ſame manner as waves ariſe in that part of water wherein a ſtone or any other body is plunged, from whence they propagate, and expand in the form of concentric circles to a conſiderable diſtance.

The velocity and extent of theſe tremours in air are known from the ſound, which is the effect of their diffuſion, and which is found to go at the rate of 1142 feet in a ſecond of time. This velocity of ſound is above 30 or 40 times greater than that of any current of air ever experienced, though excited by very great winds; beſides, ſound goes, not only ſo much faſter than the wind, but even againſt the wind, which properties of ſound deſerve a particular conſideration.

All philoſophers agree that air is the moſt heterogeneous body in nature, as being compoſed of the parts and particles of all kinds of bodies whatſoever; for our atmoſphere is the common recipient of all exhalations and perſpirations that ariſe from every kind, in either of the foſſil, vegetable, or animal kingdoms. Not only the ſpecies of ſalts, ſulphurs, metals and mercuries that are exhaled by the ſun, and excluded by the internal heat of the earth, but alſo the exhalations of ſalt and coal-pits, and of all other mines, caverns, and excavations of the earth are carried into the atmoſphere, along with what is ſent from the bowels of the earth on all ſides by the eruptions of earthquakes and vulcanos. Again, every vegetable that grows, is ſurrounded with its odorific and exuding particles; not only theſe, but the bodies themſelves, when diſſolved by rottenneſs or fire, are carried up and blended with the air. Moreover, the perſpirations and reſpirations of animals, the exhalations of their excrements, and even themſelves, when diſſolved by putrifaction or otherwiſe, are in like manner carried up and diffuſed through this univerſal reſervoir. Beſides all theſe, this ſurrounding chaos is mixed with a prodigious quantity of water, that evaporates not only from the ſeas, lakes, and rivers, but from all humid bodies round the earth, every ſeaſon of the year; as for inſtance, how often in the year are our ſtreets wet and full of puddles, and again dryed by the wind or by the heat of the ſun! And if ſo much water is carried into the air from one city by evaporation, how much, not to mention the ſeas and rivers, is carried up from all the cities, fields, lands, and mountains round the earth! Conſequently our atmoſphere is a moſt heterogeneous body.

Now if we ſhould ſay, along with ſome philoſophers, that all theſe exhalations and evaporations are compoſed of inert particles, endowed with gravity; if there was not ſome elaſtic medium or expanſive ſubſtance to ſuſpend and buoy them up, wherein they ſhould float, be blended and joined together; ſhould we not, inſtead of an extenſive and expanſive atmoſphere, fit for animals to breathe, and birds to fly in, have the earth ſurrounded with a moiſt, dark and fulſome miſt, or immerſed in a denſe mire of chaotic matter? Therefore our atmoſphere muſt have in its compoſition a vaſt ocean of matter, of an expanſive nature, void of gravity or inertneſs, which receives and buoys up all the exhalations and evaporations we have mentioned.

Without an elaſtic medium of this kind, diffuſed throughout the air, the propagation of ſound would be impoſſible, much leſs could it outſtrip the winds in velocity, or proceed in a direction contrary to them. For if the particles were inert, they would be void of all power to act; conſequently, unable to expand, propel, or reverberate, and therefore incapable of producing the tremulous motion neceſſary for the propagation of ſound. In this caſe, if by any extraneous agent theſe inert particles were ſet in motion, or excited to produce any effect; this effect could not precede their action, or be ſwifter than its cauſe. If therefore tremours were excited in theſe particles, they might, we'll ſuppoſe, excite the ſenſation of ſound wherever the moving parts actually ſubſiſted and exerted their impulſe: but the ſound thus produced, could neither move faſter than the particles, nor in a contrary direction; for as by hypotheſis they are its only vehicle, it could not move faſter than they, or go againſt them: conſequently, the motion of ſound would depend as much on the motion of the air, as the motion of a cork does on that of the ſtream which carries it down. Wherefore ſound, were it propagated by the inert and groſs parts of air, could neither go faſter than the wind, nor could it by any means go againſt it. Experience however proves, that ſound outſtrips the wind, and is propagated againſt it; conſequently, the vehicle of ſound is not theſe inert and groſs parts of the air, whoſe current produces wind, but ſome ſubtile, expanſive medium, which buoys up theſe inert particles, which reverberates independent of them, with greater velocity than they, and even in a direction contrary to their motion.

It is uſeleſs in our reaſonings on this ſubject, to take notice of the gravity of the groſs particles; for whether that property be conſidered as an innate power in them, or as a foreign one, that operates on them, its tendency is to bring them downwards, and make them converge, which is directly contrary to expanſion and elaſtic tremours. All this may be further confirmed from the concurring opinions of the greateſt philoſophers; we ſhall advert, at preſent, to that of the celebrated Boyle, who hath made a great variety of pneumatic experiments, and many improvements in this part of phyſics. "Air," (ſays this diſcerning philoſopher) "is made

" up of three different kinds of corpuſcles, " *viz.* of thoſe numberleſs minute particles " which, in the form of vapour or dry exha- " lations, aſcend from the earth, waters, mi- " nerals, vegetables, animals, &c. in ſhort, " of whatever ſubſtances are elevated by the " celeſtial and ſubterraneous heat, and thence " diffuſed into the atmoſphere: 2dly, of a " ſtill more ſubtile matter, conſiſting of ex- " ceeding minute atoms, the magnetical ef- " fluvia of the earth, with other innumerable " particles from the bodies of the celeſtial " luminaries, which cauſe in us by their im- " pulſes, the idea of light: 3dly, of an " elaſtic ſubſtance, which is the baſis of all " the other parts, and which conſtitutes the " true eſſence of air."

This great philoſopher makes an elaſtic ſubſtance the baſis of air, according to our natural eduction; and ſays farther, that this ſubſtance conſtitutes its real eſſence; to which, we preſume, all philoſophers will agree, who juſtly conſider this ſubject. Cauſes muſt always be aſſigned conſonant and adequate to their effects; for the Creator's Power was not confined ſolely to inert matter: He could therefore, create an active matter, if He ſaw it neceſſary, or uſeful for the works of nature; and we are to pronounce that He really created it, if we diſcover its exiſtence in effects unimputable to inert particles. Now, this is abſolutely the caſe. Expanſion or intrinſic activity is diſcovered in air, and it is not imputable to the inert parts thereof, as inertneſs and activity are contradictory ideas; this power then muſt either belong to another ſubſtance in the compoſition of air, or elſe be an abſolute power, not reſiding in any ſubſtance: but the latter is inconſiſtent; for the word *power*, in phyſics, only ſignifies the exertion of a material ſubſtance; the *power* of burning, for inſtance, is that peculiar exertion of fire; the *power* of wetting in water is only the aptneſs of the liquid to produce that effect; and no philoſopher will admit a power of burning without fire, or of wetting without a liquid. Neither can a power of expanding exiſt without a ſubſtance to exert that power. Therefore, beſides the inert parts of air, there mnſt exiſt in the atmoſphere an active ſubſtance, or elaſtic principle.

SECTION III.

An elaſtic Principle in Water.

FROM the queries of the illuſtrious Newton it appears, that he attributes the undulations and tremours of air and water to the ſame cauſe, to wit, an ætherial, ſubtile and elaſtic medium. In this he follows the ſecond rule of philoſophizing, *viz.* of natural effects of the ſame kind, the ſame cauſe is to be aſſigned. We ſhould alſo, in conformity with theſe rules, which are univerſally adopted, from the elaſticity of air, infer the elaſticity of water; for the ſimilarity of its effects in both is evident in every circumſtance. Circular waves of water expand on all ſides from where a ſtone is plunged, as do the undulations of the air from where a bell is rung. 2dly, The ſound goes againſt the wind, and the waves of water go againſt the ſtream. 3dly, That part of the water, where the ſtone was plunged, was removed, yet it returned again to its place, and remains there, though the circles are expanded from it on all ſides: the parts of the air, which touch the bell, were alſo removed, yet return again to their place, while the tremours and ſound are propagated on all ſides: for if the air was driven off from that place, and did not return by its elaſtic ſpring, the ringer of the bell would faint in a vacuum. Although water is not the medium of ſound, as air is, yet a ring or noiſe of ſtriking bodies will be heard through it. We cannot, after ſuch ſimilarity of effects and operations, admit elaſticity in one, and deny it of the other.

This circumſtance likewiſe deſerves attention. If a chip, a feather, or ſome other light body is left on the water at ſome diſtance from where a ſtone is thrown in, it ſhall retain its place, as would a ſhip at anchor (if the wind did not affect it) while the circular waves paſs under it. Hence, we ſee that while the floating body remains at reſt, with the particles or parts of the water it adheres to, ſome more lively medium puſhes off the circular waves, and occaſions their diffuſion: which evidently points out two diſtinct kinds of fluids in water, as the clear-ſighted Boyle has remarked in air, each operating according to its own peculiar nature, though both are agitated by the ſame cauſe. The aquæous matter is, we may ſay, at reſt, becauſe the feather retains its place, while the *elaſtic* puſhes forward with a lively motion, ſimilar to that of the ſame ſubſtance in air, whereby ſound is enabled to go ſwifter than the wind. Doubtleſs the elaſtic matter of water cannot be ſo ſwift as that of air, being more ſhackled down by the gravity and tenacity of the liquid ſubſtance which confines it.

However the elaſticity of water, though inferior to that of air, is no leſs certain; for like effects ariſe from like cauſes. If then the vibrations of a bell in open air could not affect a perſon a thouſand yards diſtant, or cauſe pulſes to act on the drum of his ear, ſo as to produce the ſenſation of ſound, without the elaſticity of the intervening medium to propagate thoſe pulſes; neither could the plunge of a ſtone give riſe to waves ten yards off, without an elaſticity in the water to propagate theſe waves from where the ſtone was plunged. The effect is the ſame in both mediums, and muſt ariſe from the ſame cauſe. The cauſe indeed acts more powerfully in the firſt caſe than in the ſecond: but this only argues a difference of energy, which is to be determined by the effects produced in a given time, *i. e.* by the ſpaces through which their undulations paſs in the ſame time. There is this further ſimilarity between the two fluids; the ſounds of different bodies or inſtruments do not intercept each other; neither will the tremours, or circular waves, ariſing from different bodies thrown into water, intercept their reſpective circular propagations. For the elaſtic ſpecies of the waves will pervade each other's dimenſions, without interruption, or confuſion. But, doubtleſs, if there be a tumult of cauſes in either, the effects produced will be confuſed; for diſorderly broken waves will ariſe from a ſcattered plunge of many bodies: as jarring ſounds ariſe from a like number of inſtruments, if not tuned, or if irregularly played. Yet in either the moſt forcible will bear ſway over the reſt.

We have alſo further proofs of the elaſticity of water in common with hard bodies. A drop of rain will rebound from the ſurface of water, whereon it falls; as does a marble or ivory ball, which is let to fall upon a flag. Daſh water againſt a wall, and it ſhall be reflected in ſcattered drops to a diſtance. Water expands with heat; for though a kettle be not filled, the water ſhall ſwell ſo high, when hot, as to flow over: and, again, when cold, it ſhall contract to its former dimenſions; ſo hard bodies will contract with cold, and expand with heat. Theſe are like effects; ſhall we not allow them to ariſe from like cauſes?

Stop the touch-hole of a gun-barrel, and put into it about a naggin of water, having wrapped paper about a bullet, or a ſmall pebble, to make it fit the bore tightly, ram it down to the ſurface of the water: then lay the britch of the barrel upon a briſk fire. When the water begins to boil, or perhaps before it is ſo hot, the bullet ſhall go off with a force, not much inferior to that cauſed by gun-powder, as may be known by its effects on a board, to which the barrel may previouſly be directed. Care muſt be taken to direct its muzzle out of the way of danger; at leaſt give the barrel an elevation greater than the height of a man, otherwiſe a miſchance may happen by an unexpected diſcharge.

It is well known that air expands by heat, and alſo that water is reduced to artificial air, is evident from the Æolipile, which is ſometimes uſed to blow up fires: and ſome think that gun-powder (whoſe amazing force is known by its tremendous effects) is reduced to an elaſtic air by fire. Now if ſuch prodigious force, excited by fire, denotes an expanſive principle in air, or gun-powder, or marks any character of an elaſtic fluid in either of theſe heterogenous bodies; ſhould not a like force mark the ſame ſubſtance in water? Which likewiſe may be infered of ſtones, wood, and all other bodies, that break, burſt, or ſwell by fire.

We may reaſon in the ſame manner with regard to the ſimilar phænomena, which we have above obſerved in air and water; for if the propagation of ſpherical waves and tremours in air, ſwifter than the wind, and in a direction contrary thereto, indicates an elaſtic ſubſtance inherent in air, ſo the circular waves expanding in water, denote an elaſtic ſubſtance inherent therein. Nay this ſubſtance is more diſtinctly and ſenſibly perceived in the latter fluid; for its undulations are ſeen to expand far and wide, while the groſſer parts of water, and the feather or chip which adheres to them, remain at reſt in their places. The ſame thing is likewiſe perceivable in all elaſtic bodies, whoſe parts remain in perfect coheſion, while a tremour is propagated throughout the whole body by ſtriking or rubbing. The vibratory tremours of a bell, while in the act of ringing, are ſo powerful, as to change its figure, to benumb the hand of a perſon in contact with it, and to communicate a ſimilar vibration to the air for a conſiderable diſtance: nevertheleſs, the parts or particles of the bell retain their places, and continue in coheſion. The parts of muſical glaſſes likewiſe retain their coheſion, while the tremours, which beget ſound, run through all parts of the glaſs, and agitate the contained water with a tremulous motion, which ſhoots in on all ſides from the circumference to the centre, without diſplacing a ſingle drop. As then the ſagacious Boyle has from the expanſion, tremours, and elaſticity of air, perceived in it an elaſtic matter, diſtinct in nature and eſſence from the groſſer ſubſtances which enter into its compoſition, may we not with the ſame juſtice conclude, that all other bodies in nature, which have the powers of expanding, ſounding, or communicating tremours, are alſo impregnated with, or have inherent in them, a pure elaſtic ſubſtance diſtinct in nature and eſſence from the groſſer matters which compoſe them, at leaſt very different from inert matter.

Let the ſceptic, who will not ſubſcribe to this concluſion, ſay, what is the cauſe of tremours and ſound in bodies; or what is the cauſe of their elaſticity: which power we have throughout the courſe of this treatiſe, proved to inhere in every kind of body, the inert reſiduum of conſumed vegetables and animals excepted. It would be abſurd to impute ſuch effects to inertneſs, that being the diſability of all ſuch powers. Nor can they be imputed to figure, which is only a neutral and ſuperficial thing, that cannot induce or beget any natural faculty. Thus by reaſoning phyſically on the phænomena of nature, and by ſome hints borrowed from the great philoſophers, Newton and Boyle, we have diſcovered and exhibited in all bodies an elaſtic ſpecies totally diſtinct from the other matter or matters which compoſe them. This diſcovery ſhews that two kinds of matter are to be admitted in nature, quite diſtinct from each other, *viz.* elaſtic and inert. There are alſo indications of a third kind; for ſome reaſons have occurred in the courſe of this work, which ſeem to ſuggeſt that *gravity* is not an univerſal property of all matter, but hath a material ſubſtance peculiar to itſelf, and diſtinct from the two other kinds already mentioned. To aſſiſt us in the further inveſtigation and diſtinction of theſe ſubſtances, we ſhall now reſolve a body by fire into its original and conſtituent parts.

LECTURE IV.

The elaſtic Principle further aſcertained, its Uſes in Nature and Mode of Operation.

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SECTION I.

Elaſtic Subſtance ſeparately exhibited.

HITHERTO we have conſidered the principle of elaſticity, as inherent in bodies and concealed within their parts. It would greatly elucidate our reſearches, and improve our knowledge, if we could now ſeparate that ſubſtance from the groſſer matters, with which it is generally united. By this means from the knowledge of its exiſtence, which we have already obtained by its ſenſible effects, we might proceed to the inveſtigation of its nature and mode of operation; the diſcovery of which will doubtleſs unfold many important ſecrets of nature. As fire then is the great diſſolvent of all bodies, we ſhall employ its agency for our preſent purpoſe.

Let trees, plants, or vegetables of any kind, be cut down in proper ſeaſon, ſo as to poſſeſs all their juices and qualities in full perfection; having dried, and heaped together a quantity of them, ſuppoſe a ton weight, ſet them on fire; immediately a ſmoke will ariſe, which will become more denſe, as the heat increaſes and diffuſes itſelf throughout the heap; afterwards a flame will break forth through the denſe vapour, which will, at length, be entirely converted into a clear ſtrong blaze with little or no ſmoke; and this will continue until the heap be reduced to coals and aſhes. But to reduce all the more ſpeedily and effectually, it will be proper to ſtir up the remains, and expoſe every part to the air. The fire, being thus fanned and enlivened, will prey more thoroughly on the ſubject, and reduce it to a quantity of ſaline aſhes, which being purged of their ſalts, will not be perhaps the twentieth, nay, the hundredth part of the original heap.

The ſalt that theſe aſhes contain may be entirely removed by ſucceſſively waſhing and drenching them with freſh water. Aſhes thus depurated, Doctor Boerhaave calls *pure virgin earth;* adding, that it is *ſubtile, without any coheſion, immutable in the fire, the ſame in every plant, and in every quality like the aſhes of burnt animals.* We ſhall conſider more of his remarks, after propoſing and conſidering ſome queſtions relative to the heap of vegetables, and the changes it has undergone.

This pile conſiſting of wood, bark, leaves, flowers, &c. to the amount of 20 hundred weight, is by fire reduced to a ſmall heap of ſaline aſhes, not 50, perhaps not 20 pounds weight, which when depurated to pure pale aſhes, will be much leſs: and perhaps 10 pounds of ſuch a reſiduum would not remain, if the heap originally conſiſted of paper, or linen. Now the firſt inquiry to be made is, what has become of the weight, or gravity of the heap; for its aſhes retain not the hundredth part thereof? A ſecond queſtion is, what has become of the coheſion, elaſticity, firmneſs, odours, colour, guſt, medicinal virtues, in ſhort, of all the powers and qualities, which the different parts of the heap originally poſſeſſed, and which have been reſolved, ſeparated, and, I may ſay, diſperſed by fire?

To anſwer theſe queries, we ſhall borrow what light we can from Doctor Boerhaave, who, to make inquiries ſomewhat ſimilar to the preſent, in the beginning of the ſecond volume of his Elements of Chymiſtry, by ſeveral orderly proceſſes ariſing from different degrees of heat, reſolves a roſemary plant into its various conſtituent parts. His firſt proceſs is diſtillation with an heat of 85 degrees, like that of ſummer. By this eaſy extraction he gains a liquor, which is apt to be concocted by the heat of the day, and to exhale at night in the form of that odoriferous effluvia perceived in fields and gardens on ſummer-evenings. He afterwards ſhews, "that this liquor contains an ele-
"mentary water, and the *ſpiritus rector* of
"the plant; which ſpirit, though it is in
"an exceeding ſmall quantity, yet is won-
"derfully efficacious, and gives to every

"plant its diſtinguiſhing ſmell and taſte,— "and being of a very *mobile active nature,* "affects the nerves, puts the ſpirits in motion, and quickens them, when they "are languid." (p. 10.)

The remaining plant, having loſt, with its volatile parts, its colour, and for the moſt part its ſmell and taſte, is infuſed with pure rain water heated to the degree next to that of ebullition. By this ſecond proceſs a liquor is obtained of a ſaponacious nature, which is reſolved into water, oil, a ſalt and a reſin; and contains all the virtues of the plant, which in this ſtate ſoon evaporate, and leave the remaining liquid vapid, without ſmell, or taſte: wherefore, to conſerve theſe virtues, he by a third proceſs, and a greater heat of this decoction, makes a ſyrop, a jelly, or a rohob, which may laſt for years, and is therefore laid up for future uſe.

Having gained by the foregoing proceſſes all the oils, ſalts, ſpirits and juices, that can be extracted from the plant by the greateſt action of boiling water, he takes out the ſkeleton plant, whoſe leaves and tendereſt parts, even its hairs, apices, and lineaments retain their form, though ſapleſs and ſhriveled. He then makes a fourth proceſs on the ſame plant by laying the ſapleſs ſkeleton upon an iron ladle, to dry and burn over a clear fire without any ſmoke. In ſome time the whole grows red hot; and 1ſt, A ſmoke ariſes continually growing thicker and blacker, and at length becoming a pitchly vapour. 2dly, It ſends forth a ſtrong ſmell of ſomething burning. 3dly, When the vapour is exceedingly black, and the ſmell moſt fetid, there at once burſts forth a bright flame, the ſmoke diſappears, and the ſmell grows conſiderably leſs. 4thly, The herb acquires a very black colour before the flame appears. 5thly, When the flame is extinguiſhed, the leaves have loſt their blackneſs and become white. If any part ſtill remains black, there the leaf continues to ſparkle, ſo long as there is the leaſt portion of blackneſs left. But when the preceding flame and theſe ſcintillations have conſumed all the blackneſs, there then remains nothing but white aſhes, perfectly inſipid and inodorous, which cannot by any action of the fire be made to produce ſparks any longer: wherefore, like the ultimate reſiduum of our burnt vegetables, they are fit for making coppels. 6thly, It is moſt remarkable of all, that though the herb has borne ſuch a violent action both of the fire and flame, yet, the form of the roſemary is to ſuch a degree preſerved, in theſe white aſhes, that if you examine one of the leaves, as it lies, with a microſcope, it diſcovers, not only the original ſhape of the roſemary, but even the down, hairs, protuberances, lineaments and lacunæ, as evidently, as if the herb was ſtill entire; yet, on the ſlighteſt touch or blaſt they drop to duſt. He alſo remarks, that the laſt oil cannot be ſeparated from a plant, except by fire, and in the open air. (p. 19.)

In his paragraph on the uſe of the laſt proceſs, this judicious chymiſt goes on thus: "Hence we learn that water, with the aſſiſt-"ance of ſo much fire as it takes in when "it boils, is capable of extracting from ve-"getables every thing that is ſaline, as well "the volatile part as the fixed.—All the "medicinal, nutritive, and poiſonous qualities "of vegetables reſide abſolutely in that part, "which by decoction with water may be ex-"tracted from them. And the conglutinating "oil (that then remains with the terreſtrial "elements) has nothing at all ſingular in it,

“ nor the earth, when quite alone.” He obſerves however, that this laſt oil and the earth of the plant are inſeparable from each other, except by fire, and that in the open air. For the oil ſtill remaining in the leaves after decoction diſcovered itſelf, when burning, by a thick ſcented bitter black ſmoke, which was afterwards converted into flame, it ſhewed itſelf alſo by the black colour which the plant acquired, when it began to burn and turn to a coal. Boerhaave alſo takes notice, that the herb held in a ladle covered with an iron plate over the ſtrongeſt fire will burn, and become a brittle black coal, of a bitter taſte; but will never kindle to a flame, or grow white, until the cover be taken off. But when it is expoſed to the air, it will immediately burſt forth in a flame, and ſoon be converted into white aſhes: whence, he infers that it is *this conglutinating oil that connects the terreſtrial elements into coherent ſtamina*, which are diſſolved, when this is ſeparated from them: for when once this laſt oil is totally conſumed, there is no longer any coheſion, but the terreſtrial parts ſpontaneouſly drop aſunder. (p. 20.)

The pinguous parts of vegetables this Author holds to be threefold: 1ſt, the oily ſcum: 2dly, the pinguous part of the decoction: and 3dly, this conglutinating oil, eperable only by an open fire. As for the other part of vegetables, which remains after the extraction of this oil, he ſtiles it (page 21) "a mere virgin earth, ſubtile, without cohe-"ſion, immutable in the fire, the ſame in eve-"ry plant, and in every quality like the aſhes "of burnt animals, without any difference at "all. This it is, he ſays, that gives a firm ba-"ſis to animals and vegetables; and this, pro-"cured from either one or the other, the aſſay-"ers find equally proper to make their teſts of. "If you mix water with theſe looſe aſhes, they "acquire ſome degree of tenacity, as in the "teſts juſt mentioned; but if you work them "with a proper quantity of oil, they cohere "more ſtrongly. Oil therefore and earth, he "ſays, compoſe the ſolid ſtamina of vege-"tables."

We have ſeen, in the courſe of the firſt Lecture, that the eſſence of any ſubſtance is inſeparable therefrom; but that one ſubſtance with its eſſence, *i. e.* one principle is ſeparable from another. This ſeparation is experimentally exhibited in that of the aſhes of vegetables, and their conglutinating oil (which according to Boerhaave, is performed by fire alone, but we ſhall add, by putrifaction alſo) this ſeparation, I ſay, is experimentally exemplified; for, although this oil, which connected the terreſtrial elements into coherent ſtamina, was by nature intimately united, and contextured through every conceivable part of theſe elements; yet fire ſo penetrated the moſt intimate parts of the plant, as to extract and diſlodge that adheſive oil, and carry it off in the form of ſmoke and flame. And what is very remarkable, theſe contexturing adheſive oils are ſo perfectly extracted and exterminated, as to leave nothing behind, but pure virgin earth, without ever changing in the leaſt, or diſcompoſing the form of the leaves, even of their ſmalleſt hairs or fibres, which, by the way, demonſtrates, that figure is only a mere poſition of inert matter, and nothing active or efficacious in body.

From the difference between the qualities of the oils and the aſhes, which were ſeparated from them, we muſt neceſſarily conclude, they are ſubſtances entirely diſtinct: for the aſhes or virgin earth while pure, are taſteleſs, ſcentleſs, and colourleſs, incapable of feeding flame, or of being transformed thereby: they have neither coheſion, elaſticity, nor any other quality, except that they are ſomewhat heavy, and capable of becoming a *nidus* for ſome other principle or ſpecies of matter to reſide in, whereby they may acquire coheſion, and poſſeſs the qualities of the ſpecies of matter united with them. The oils, on the other hand, had ſmell, taſte, coheſion and elaſticity, and were a nutriment to fire and flame, which transformed them to light: conſequently, theſe aſhes, and the oils which were ſeparated from them, differ in qualities, ſubſtance and eſſence.

Now to determine the eſſence of this oil, we obſerve, that it poſſeſſed elaſticity in every ſtate. In the form of flame or light, it was elaſtic, elaſticity or expanſion being the eſſence of fire; in its original form it was alſo elaſtic, as it gave that property to aſhes, otherwiſe inert. We alſo find that elaſticity is the only property which attends the oil, and is inſeparable from it in every ſtate. Neither the light and heat it had in one form, nor the ſmell and taſte it had in another, can be called its eſſence, becauſe they were entirely loſt in the change of its form: conſequently, as the eſſence always attends its ſubſtance, and is inſeparable from it; elaſticity, which attends oil in every form, is its real eſſence.

This elaſticity is an active property, and muſt animate an active ſubſtance, totally diſtinct from the aſhes, which are perfectly inert; for ſubſtances are as their eſſences; but the eſſence of oil is active, therefore its ſubſtance is active: conſequently, it is perfectly different from the ſubſtance of virgin earth. Now if gravity be not eſſential to virgin earth, this ſpecies of matter muſt be void of every eſſence and property, except thoſe implied in the idea of matter, which diſtinguiſh it from ſpirit, ſuch as extenſion, ſolidity, and tangibility. Theſe aſhes therefore are ſimply what Boerhaave ſtiles them, a baſis of firmneſs to plants and animals, which muſt acquire their growth, elaſticity, and other lively properties by an accretion of the active matter.

There are conſequently in nature (if this be not a ſolitary inſtance) two kinds of matter, *viz.* the active and the inert. The inert matter is the baſis of every kind of body, in which the active is harboured: the active, on the other hand, is the ſupporting ſubſtance of active material powers, ſenſible qualities, and medicinal virtues, all which it brings with it into inert matter, when theſe two ſubſtances are united together; and this being the caſe in moſt bodies, is the reaſon why they generally give indications of inertneſs and activity at the ſame time.

From theſe obſervations, the ſolution of the ſecond queſtion propoſed, with regard to the burnt vegetables, appears perfectly obvious: for, as ſoon as the fire diſſolved the conſiſtency of the plants, the active ſubſtance confined therein broke forth in the form of flame or light, with its native expanſion heightened by fire, and carried off into the atmoſphere all theſe lively powers and qualities whereof it is the baſis, and which it enlivened and ſuſtained in the vegetable bodies, while it remained in their compoſition.

As to the queſtion relative to the weight of the heap, we ſee a ton of vegetables reduced by fire to a few pounds of inert matter; conſequently, above nineteen hundred weight has diſappeared; ſhall we therefore conclude, that all this weight has been carried off by ſmoke and flame? This ſeems improbable;

for, whatever be the material cauſe of gravity, certainly it has not a tendency to aſcend, its ſole tendency being convergent and centripetal. On the other hand, flame has ever a contrary propenſity, *viz.* to riſe and expand; and ſmoke, which we find to be the naſcent form of flame, is analogous thereto, and ſhould have the ſame tendency, though in a lower degree: conſequently, when fire diſſolved the coheſion of the body, and ſeparated its elements from each other, as we have ſeen in the ſeparation of the inert reſiduum and the ultimate oil of the plant, when, I ſay, the elementary ſubſtances were thus diſunited, each purſued the propenſity peculiar to its nature; the elaſtic matter, releaſed from its confinement, fled into the atmoſphere, its proper reſervoir, and the matter of gravity muſt have ſunk with native propenſity towards the centre of the earth, a ſmall part of it only ſtill remaining with the aſhes and ſalts on the ſurface. And, as eſſences muſt ever accompany their peculiar ſubſtances, the elaſtic matter, in its flight, carried off the elaſticity, ſmell, taſte, and other lively qualities peculiar thereto, along with the oils and ſpirits, on which, according to all chymiſts, the virtues of a body depend. In the ſame manner, the ſubſtance of gravity, in its departure, was accompanied by its eſſence, and left behind no weight, but what might be produced by a ſmall portion of that ſubſtance, ſtill reſiding in the ſalts and aſhes.

The heap of vegetables is therefore in the groſs, reſolvable into three diſtinct ſubſtances, to wit, the inert matter, the elaſtic matter, and the gravitating matter: now as gravity is a ſpecies of attraction, or at leaſt acts with centripetal force, it might ſeem that the gravitating matter had at firſt produced the coheſion of the plants, and afterwards, in its departure, carried it off, together with their weight. But Doctor Boerhaave imputes coheſion to the adheſive oil, ultimately extracted by fire; we ſhall therefore ſuſpend our judgment on this head, until we treat particularly of attraction, and learn ſomething of the nature and powers of thoſe ſalts inherent in bodies.

Two objections may be raiſed againſt this theory, but they are of no great force. 1ſt, It may be ſaid, that this ſuppoſed matter, which produced gravity in the vegetables, and afterwards bore it away, is a mere creature of the imagination, whoſe reality is not to be admitted; eſpecially, as Sir Iſaac Newton, tho' he confeſſes he knows not what the cauſe of gravity is, * ſays, it has ſome other cauſe beſides denſe matter, which, he declares, was the tacit opinion of the ancient philoſophers of Greece and Phœnicia. 2dly, It may be alledged, that the gravity, as well as the other properties and qualities of the bodies, evaporated in the form of ſmoke and flame, which gravitating fluids were preſſed upwards by the ſuperior weight of the ſurrounding atmoſphere.

As for the firſt objection, it muſt be owned, that the materiality of gravity has not hitherto been determined, or diſcovered by ſenſe, except by the weight, and other ſuch material effects that we ſee it produce; but theſe we conſider as ſufficient vouchers for the materiality of their cauſe, unleſs we are ſo abſurd as to ſuppoſe, that while elaſticity and other lively powers are produced in body by its containing a certain ſpecies of matter to which they belong, gravity is produced in it by a *ſpirit*, or by a ſubſtanceleſs virtue, or by nothing at all. If none of theſe ſuppoſitions be admiſſible, we muſt allow gravity to be the endowment of a material ſubſtance, although it be not diſcernible to ſenſe, except ini ts effects. Nor is this the only caſe, in which the effect alone conducts us to ſuch a conception of its cauſe; we cannot ſee the air, though compoſed of a thouſand exhalations, yet we admit its materiality. Its pure baſis, the elaſtic matter, is neither ſeen in itſelf, nor is its force felt ſo much as that of gravity; yet its buoyant power, its tremours and the propagation of ſound manifeſt its exiſtence, and point out its eſſence, *viz.* expanſion. We neither ſee nor feel thoſe rays of light which depict objects on the retina, except by the viſibility of theſe objects; yet we are convinced of their reality and operation; all which agree with our third propoſition, that material effects and operations ariſe from material cauſes. Therefore, although we ſee not the ſubſtance of gravity, from reaſon and experience we are induced to think it is a material agent, endowed with its peculiar eſſence. This eſſence, according to our fourth propoſition, is known by its propenſity, which, from common experience in all gravitating bodies, is ſeen to be towards the centre: therefore, as ſubſtance and eſſence are inſeparable, and as phyſical agents act according to their propenſities, this gravitating ſubſtance was no ſooner ſeparated from the vegetable ſtamina, wherein it was contextured with the other matters of the plants, than it purſued its natural propenſity to deſcend, and ſo it carried off that weight, which its reſidence in the body had occaſioned. This explanation may alſo be applied to the loſs of weight, which candles, coals, or any other bodies ſuffer, when reſolved by fire into their conſtituent parts. Nor do we imagine, that an implicit faith is to be given to the tacit or explicit opinions of Grecian, Phœnician, or Engliſh philoſophers, only in as much as they are founded upon phyſical reaſoning and fair experiment, neither of which has been employed upon the preſent queſtion.

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* See ſecond advertiſement, prefixed to the ſecond edition of his optics.

2dly, The ſuppoſition that the whole weight, which the vegetables loſt in burning, was carried away by the ſmoke and flame, is at leaſt as arbitrary as our explanation, and far leſs conſonant to reaſon and experience; for the black coal to which paper is reduced by flame, is heavier than the white aſhes, into which it is afterwards converted by the devouring ſcintillations which run through it, as Boerhaave deſcribes in his fourth proceſs; yet the conſuming ſparks, which ſet the gravity of this black coal at liberty, produce neither flame nor vapour to carry it off. If they be ſaid to produce an imperceptible one; we may as well admit the imperceptible effluvia of gravity deſcending to the earth, according as the body is diſſolved; and doubtleſs the agent which cauſes the deſcent of all bodies, muſt itſelf, when diſengaged from them, deſcend with more rapidity.

What has been here ſaid on gravity was merely occaſional, thoſe obſervations having naturally preſented themſelves in our phyſical analyzation, which may hereafter aſſiſt us in exploring this occult cauſe. However, neither the analogy propoſed, nor the conformity of our ideas on that ſubject to reaſon and experience, is to be underſtood as intended for a proof that gravity ariſes from a diſtinct ſpecies of matter: that ſubject is too diſtinct from the preſent, and too extenſive in itſelf to be compriſed in this volume: what we have had here in view was to diſtinguiſh, and ſenſibly exhibit the ſubſtance and properties of the elaſtic matter, by ſeparating it from the other principles of body. Having thus confirmed and improved our former reſearches after this ſubſtance, we ſhall now conſider its effects and uſes in nature.

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SECTION II.

Its Uſes in Nature.

BY the art of brewing the alimental and inebriating ſubſtance of malt is removed from the grain, and ſuperinduced upon water, whereby ale or beer is made; a kind of beverage which nouriſhes and invigorates the frame, but which, if a man takes it to exceſs, will debilitate him ſo, as to make him ſtagger and ſtumble. Simple water is void of theſe qualities: nor will all the boiling or fire imaginable communicate ſuch qualities to it. Doctor Boerhaave, as we have lately ſeen, ſhews, that the powers and virtues of vegetables depend upon their oils, ſalts, and ſpirits; theſe oils, he alſo remarks, are of a *mobile, active nature, affect the nerves, and put the* *ſpirits in motion.* Now we have ſhewn that the elaſtic matter is the ſubſtance, whoſe eſſence is activity; it muſt therefore be the baſis of all theſe powers in the oils, and in the beer.

Conſequently, as powers, (by our fourth propoſition) belong to, and are accompanied by adequate eſſences, it follows, that the medicinal and alimentary qualities could not have paſſed into water, without the eſſence to which thoſe powers belong. Again, ſince, (by our fifth propoſition) the eſſence is inſeparable from its ſubſtance, the eſſence above mentioned was vehicled into the water by its ſubſtance, that is, by the elaſtic matter; which being impregnated in the water, rendered it a nouriſhing, ſprightly, inebriating liquor.

The effects of this liquor confirm this explanation; for, when taken in moderation, it diffuſes a gentle warmth throughout the body, and occaſions a lively motion of the ſpirits; but, when taken in exceſs, it cauſes an irregular motion in the ſpirits and nerves, and thereby occaſions inebriation: both which effects are unimputable to inert matter; but highly conſonant to the elaſtic, which is the baſis of flame, and the ſource of tremours. There cannot be an effect without a cauſe, and the cauſe is always adequate to its effect; therefore, as the water had not ſuch powers, and was incapable of ſuch effects before decoction, it muſt have derived them from ſome ſubſtance therein acquired: now the ſubſtance acquired in decoction, and adequate to the ſubſequent effects, was the elaſtic matter of the decocted ſubjects, whoſe eſſenſe is expanſive vigour and activity, when ſtimulated by heat, or by any foreign action. This ſubſtance then, being imbibed and heated in the body, ſhould naturally excite tremours, and a lively circulation of the animal ſpirits; which, when moderate, occaſions chearfulneſs; but when violent or exceſſive, diſturbs their regular courſe, and renders the frame tottering and diſordered.

From our rules it appears, that qualities denote their eſſences, and that the eſſence indicates the ſubſtance, to which it belongs: thus all lively material powers and qualities muſt be produced by an active eſſence; and if the eſſence be active, ſo muſt its ſubſtance. On the contrary, neutral qualities alone are adequate to inert matter, ſuch as figure, extenſion, and tangibility, which, at the ſame time, are eſſential to all kinds of matter; but are incapable of producing heat, or even tremours, without ſome motive cauſe.

As a further proof that the powers and qualities were transferred by a tranſpoſition of their elaſtic baſis, it is the opinion of chymiſts, founded on univerſal experience, that the powers and qualities of a body depend chiefly on its oils and ſpirits: now theſe oils and ſpirits poſſeſs elaſticity in an high degree; for beſides the proofs we have already given of the great quantity of elaſtic matter they contain, it muſt be remarked, that oils and ſpirits are the peculiar *pabulum* of flame, whoſe eſſence is expanſion, and whoſe baſis is the elaſtic matter. Whence we ſee, that the ſame ſubſtance, to wit, the elaſtic matter, is the ſource of expanſion in flame, and the baſis of powers and qualities in vegetables: we likewiſe obſerve, that the power of expanſion, which is the true eſſence of the elaſtic matter, attends this ſubſtance from the moſt crude ſtate of the body, in which it reſides, to its ultimate degree of ſublimation in the form of flame, and is ever inſeparable from it: for in the crude ſtate of a kernel, expanſion enlivens and propels the qualities, with which the elaſtic matter of oil endows that body, and thereby enables it to act ſtrongly on our ſenſitive organs. When oil is blended with inert matter, as with aſhes, the ſame expanſion, which ſtill attends the elaſtic matter of oil, endows the compound with elaſticity and other lively powers: thoſe powers the elaſtic matter carried off when it abandoned the vegetables in the form of flame; and thoſe powers alſo it brings into water, when it is united therewith, and thereby converts that inſipid liquid into an agreeable and ſalutary draught. Thus Divine Providence, by creating the ſubſtance and eſſence together, and rendering them inſeparable, has enabled us to ſuperinduce the qualities of different bodies upon water, in the form of juices, beer, ale, ſyrops, and ſpirits, to be barrelled or bottled up for the neceſſities and conveniencies of life.

The ſuperinducement of the qualities of various ſubjects on water, beſides the art of brewing, is exemplified in ſeveral other arts and branches of buſineſs, ſuch as pharmacy, dying, diſtilling, cooking, &c. in each of which a ſkilful artiſt, by ſteeping or blending certain ſeeds, plants, or other bodies, obtains the qualities he means to transfuſe on that fluid. All this is effected by giving the water different degrees of heat, capable of diſuniting the elaſtic matter, *i. e.* the baſis of theſe qualities from the native ſubject, wherein it has been contextured by the operations of nature: for fire being communicated to it, pervades, by its ſubtility, the moſt intimate particles of the body, and by its expanſive action ſends forth the latent qualities and innate virtues of the ſubject, as we have ſeen by the ultimate reſiduum of burnt vegetables, from which all their qualities were extracted by fire.

We have ſeen that active powers and qualities belong to active ſubſtances, and that a power without a ſubſtance is but an abſtract idea, nothing really exiſting; for did a ſubſtanceleſs power exiſt, it would want all material efficacy and impelling force, and would conſequently be incapable of affecting our organs, or impreſſing the idea of qualities. Therefore water acquires theſe powers and qualities only by the acquiſition of the elaſtic matter, which is their baſis, that gives them ſpring and vigour, as is evident from this, that the water, of which beer is made, is at firſt an inſipid colourleſs fluid; but after the infuſion of proper ingredients, not only acquires colour and flavour, but alſo a ſtrength of body, and a tenacious ſubſtantial nature, which are plain indications of an acceſſion of the elaſtic ſubſtance. But what renders a transfuſion of this lively matter from the vegetables to the water ſtill more indubitable, is, that thoſe loſe of it, what this gains; and above all, the property of inflammability, which was before quite foreign to water, and which eſſentially depends on the elaſtic matter, is ſometimes acquired by decoction, but is likewiſe greatly diminiſhed in the decocted matters.

Thus we ſee pure limpid water changed to a ſtrong, nutricious and ſpirituous liquor, having acquired an inebriating power, richneſs of quality, flavour, colour, and perhaps inflammability, while all theſe qualities are at the ſame time either entirely loſt, or greatly diminiſhed in the infuſed or decocted ſubject. All this proves, that the elaſtic matter, which ſupported thoſe qualities in the body, was extracted from it, and that this ſubſtance and its inherent qualities, were transfuſed on, blended with, and impregnated in the water, which thus becomes a rich lively liquor.

In order to conceive how this elaſtic matter, with the qualities it ſupports and informs, could be induced to leave the ſolid body, wherein it was contextured by nature, and to incorporate with a fluid, to which it had no ſuch affinity: we muſt conſider firſt, that every vegetable, during its infant ſtate, only exhibits indications of its ſpecific form and kind, but poſſeſſes not the powers and qualities peculiar to its nature in their ſtrength and vigour, until it acquires due growth and maturity: nor will even age, and the juices of the earth, give natural perfection to its powers, qualities, and growth, without a free acceſs and circulation of light and air; for without air, plants or animals will not thrive: neither are fruits growing in the ſhade ſo good as thoſe, which enjoy a ſtronger light; and to induce the proper reliſh and flavour, and therefore to give them full perfection, like thoſe growing between the tropics, or in hot climates, they muſt enjoy a clear and briſk ſunſhine. Whence we ſee, that the perfection of all their qualities, depends chiefly on the quantity they acquire of theſe accretive ſubſtances, air and light. Now the elaſtic matter is the baſis of the former, and is the ſame ſubſtance with the latter; which is a proof *a priori* that the elaſtic matter is the ſource and enliving ſubſtance of the powers and qualities in body.

As for the weight of growing bodies, it may in the ſame manner accrue from an accretion of the gravitating effluvia, which along with air, light, moiſture, and the alimental juices of the earth, are continually entering into their compoſition. Theſe accretive ſubſtances are moulded and aſſimilated, during the growth of the body, to its form and nature, by virtue of that law which the Creator made, when having formed all beings in the full perfection of their reſpective natures, he ordered thoſe he deſigned for propagation to bring forth their kinds, each having in itſelf its proper ſeed. Whence we ſee that the animal, as well as the vegetable, brings forth its young or kind without art or contrivance to form the embryo, to mould, or to aſſimilate it to its own nature; for even the moſt rational and ſagacious woman knows not how her child gets being, form, life, or perfection, otherwiſe than by the Divine efficacy, with which the Omnific Word endowed this law of procreation. If metals or foſſils propagate, grow, or increaſe, as vegetables do, it muſt be through the efficacy of the ſame word, and under the ſame law, that they alſo, in their accretion and growth, aſſimilate theſe matters to their nature and kind, and impregnate them with their diſtinctive powers and properties. Thus, the elaſtic and other elementary matters muſt put on, and change to the nature and qualities of the body, which they conſtitute; as ſhall more fully appear in the ſequel of this work.

However, what we have here to remark is, that every growing body will accumulate and condenſe in its growth a vaſt quantity of our elaſtic matter. Again, we are to obſerve, that Nature ever tends to an equilibrium. Her majiſterial powers *Heat* and *Cold* (whoſe material principles ſhall be hereafter exhibited) are ever in oppoſition, and yielding and triumphing alternately, by their various influence excite and ſuſtain all her motions and operations. From this tendency to an equilibrium, no ſooner does a body of air, which has been compreſſed and condenſed in any confined ſpace (whether naturally by cold, or artificially, as in the air-gun) gain an opportunity to expand, than it burſts forth with innate propenſity, and diffuſes, until it be in equilibrio with the ſurrounding atmoſphere. In the ſame manner the elaſtic matter, which has been condenſed and contextured in the body during its growth, when ſet free by heat, or fire, as if from a priſon, iſſues forth, and diffuſes, in water, by decoction, or in air, by torrifaction, until it be in equilibrio with the elaſtic matter of either medium. This is the reaſon of its ſeparation from the ſolid body, in which it was contextured, and of its transfuſion. It now remains to examine, why it ſhould equally blend with, and impregnate all parts of the water.

We have already hinted, and ſhall hereafter demonſtrate, that light, if not the ſole ſource and origin of the elaſtic matter, is the chief part thereof. The coheſive power which Boerhaave attributes to the conglutinating oil that connects the terreſtrial elements into coherent *ſtamina*, denotes alſo an *adheſive* principle in this baſis of powers, whereby an elaſtic firmneſs is given to body. But as we have not as yet ſufficient *data* for the inveſtigation of that new ſpecies of matter, we ſhall only conſider the other ingredient, to wit, light, to which the elaſtic matter owes its expanſive vigour. Wherefore, as there are different ſpecies of light diſtinguiſhable by their colours, ſo there are different ſpecies of the elaſtic matter, which, perhaps, only differ by their denſity or tenuity, or by the different portions of the adheſive matter (if ſuch there be) which bind down and conſtipate that light, according to the different natures of the bodies, in which they inhere, having been aſſimilated to the nature of each particular body, in its formation and growth, either by coction, or accretion, through the Divine efficacy of that word which regulates the formation and nature of every being. Thus, the food of animals is variouſly aſſimilated to fleſh, ſinews, bones, &c. which differ vaſtly according to the ſpecies of the animal. The elaſtic matter is alſo variouſly conſtituted in the ſpirituous, nutritive, and conglutinating oils of a vegetable; for Boerhaave finds a diſtinction between theſe ſubſtances, although the elaſtic matter is their common baſis, which gives them elaſticity, while in the plant, and expanſion, when changed into flame. When, therefore, the elaſtic matter, which inheres in a vegetable or animal, is ſet looſe by decoction, it blends and incorporates with the elaſtic matter of the water; and as that of the water is inherent in every particle thereof, the elaſtic matter of the body, blending with it, alſo becomes univerſal; and pervading all parts of the fluid, every where diffuſes the glutinous, ſpirituous and other qualities, which it ſupported in the vegetable. Thus, through the ſameneſs of ſubſtance in the various ſpecies of elaſtic matters, they incorporate by coction, and the qualities of different bodies are united together by the union of this baſis, which becomes their common *vinculum*.

SECTION III.

Other Phænomena thereby explained.

EVEN without the aſſiſtance of heat, the powers and qualities of different bodies, whether ſolid or fluid, will, in many caſes, unite by a conſonance of their elaſtic matters, which form a common cement to bind them together. For inſtance, when oil is thrown in ſcattered drops on the curled ſurface of a pool at the windward ſide, the water will ſettle to a level poliſhed ſurface, as far as the oil is diffuſed by the wind. In the ſame manner a poliſhed tract, as if a glaſſy ſurface, is obſerved in the ſea after a ſhip, where the fluſh or pinguid water, wherein mariners boil their meat, has been thrown over-board: which ſhews, that the elaſtic matter, which is the baſis of oil, and the matter, which in a ſtorm proceeds from water in luminous emanations, incorporate, and thereby unite both fluids, ſo as to occaſion a ſmooth glaſſy ſurface, as far as the oil or greaſy water is diffuſed: for experience proves theſe two fluids to be entirely immiſcible and repugnant, except in that lively ſubſtance, which, being common to both, forms between them a bond of union. Nor are brewing and infuſion the only methods of extracting and ſuperinducing on water the qualities of vegetable or animal bodies with their baſis the elaſtic matter; theſe operations are alſo performed by expreſſion. This is evident, as well from the ſtrength and ſpirit of the wines, which are expreſſed from grapes, as from the fermentable, intoxicating, and ſometimes inflammable qualities of thoſe domeſtic wines we extract from apples and other fruits; all which qualities clearly point out the power and action of the elaſtic matter, which ſuſtains them, invigorates their operation, and enforces their effects: which, ſurely, cannot be imputed to any ideal quality that could be imagined without a ſuſtaining ſubſtance. Beſides, theſe powers and qualities indicate their eſſence, which again requires an adequate ſubſtance. And, as a further proof that the elaſtic matter is the vehicle by which qualities are tranſpoſed, it is remarkable that thoſe vegetables, whoſe juices have been thus extracted, will not, if ſet on fire, afford an heat or flame ſo ſtrong, as they would have done before expreſſion; becauſe the quantity of elaſtic matter, which is the baſis of flame, and which gives vigour to heat, is greatly diminiſhed in the reſidual or broken body; this body having loſt, with its juices, an adequate ſhare of that lively ſubſtance; I ſay, an adequate ſhare, becauſe a greater quantity is extracted, according as the preſſure is greater or more conſtant. Expreſſion may therefore be continued ſo as to affect the conglutinating oils of the rudimental ſtamina, eſpecially if the ſubject be pounded and moiſtened; if this ſucceed not, coction may be added to expreſſion.

On account of this relation between the preſſure and the extract thereby obtained, by various degrees of preſſion, as well as by various degrees of heat, different degrees of ſpirits and oils are procured, whoſe volatility, or ſpiſſitude may denominate the different kinds of elaſtic matter, which give them efficacy and vigour. Thus, by the firſt preſſure, or elſe by a ſlight heat of infuſion, we gain the firſt vintage, which is a volatile generous liquor, of genuine flavour and ſparkling hue, that contains the virgin qualities of the ſubject compreſſed: hence, the opening lively nature of honey that bees make from the exuding juices of flowers and bloſſoms. By a greater preſſure, or a ſtronger heat, a liquor comes forth more balſamic; and by a ſtill greater heat or preſſure, the extract becomes more glutinous; which gradation ſeems to denote greater degrees of denſity in the baſis which ſupports theſe ſucceſſive qualities. The qualities and virtues of theſe extracts are ſuperinduced on water, by mixing both together, whereby their elaſtic ſpecies blend and unite equally throughout the whole compound fluid; ſo that every drop of the water is impregnated with the qualities of the extract.

The diſſolution of an animal body, by putrifaction, viſibly exhibits the flight of the elaſtic matter, with its powers and qualities, from their native reſidence. For during ſome time after the animal is killed, while the fleſh retains its elaſticity, it alſo retains its reliſh and nutritive ſubſtance: but ſoon after, when it inclines to putrifaction, its ſtrong ſmell denotes a retreat of that ſubſtance under the form of a rancid effluvium, the loſs of which will conſequently reduce the plumpneſs and elaſticity of the fleſh ſo decaying. This effluvium will ſtill become more denſe and rancid, according as the fleſh waſtes, and will, in a dark place, ſhew a glow of light: and in this light all the powers and qualities of the body, its elaſticity, firmneſs, ſmell, taſte, &c. ſhall as effectually depart, as they did under the ſame form of light and vapour in the inſtance of torrifaction; and at length, as was the caſe in that inſtance, ſhall leave no part of the body behind, except a little duſt or inert matter.

Now, during this ſeparation and emigration of the elaſtic matter, while this ſubſtance and the qualities it ſuſtained were going off in the form of light, and diffuſing through the atmoſphere, the gravitating matter looſing its ſupport, muſt alſo have followed its propenſity into the earth, and have carried with it the original weight of the body; which alſo happens when the animal body rots under ground: in this caſe, at leaſt, certainly the matter which gives weight to the body will not aſcend, as do its volatile ſubſtances. Neither can any reaſon be alledged why it ſhould riſe, be the ſituation of the body high or low; on the contrary, reaſon dictates, that when the body is reſolved into its component parts or principles, each muſt follow its natural propenſity. The diſſolution of a body is only a diſunion and ſeparation of its concrete principles; which being effected, they cannot aid or ſuſtain each other, but become free, unconnected and independent, without any let or impediment to their innate power. This power conſiſts in the eſſence, which is inſeparable from the ſubſtance, and at the ſame time, determined to its propenſity. As, therefore, the elaſtic matter, when reſtored to its original ſtate, which is that of light, followed its propenſity and diffuſed into air; ſo the principle of gravity likewiſe, when ſet free by the body's diſſolution, follows its propenſity and ſinks to the earth, unto which it makes all neighbouring bodies, that it can affect, alſo tend.

In all theſe different inſtances of torrifaction, decoction, fermentation and putrifaction, we have ſeen that the elaſtic matter, and the qualities it ſupports and invigorates, were together ſeparated from the body, in which they were naturally incorporated and elaborated during its growth and maturation. In two of theſe inſtances, the elaſtic matter and its qualities went off together into the air, in the form of vapour, flame, or light: in the other caſes, it diffuſed through water, and impregnated that fluid with all its qualities, which was effected through the conſonance or ſimilarity of temperament between the elaſtic matter, ſupporting theſe, and that inherent in water. For this ſameneſs of nature and temper facilitates the union of their elaſtic matters, which thereby form a common vinculum to bind all the qualities together, and detain them in the water.

The ſame conſonancy between their elaſtic matters alſo forms a common vinculum to blend, and equilibrate bodies very different in qualities and ſpecific gravities. If pieces of gold, ſilver and copper, be fuſed together in a furnace and caſt in a mould, the compound maſs, when cold, will have the ſame qualities and ſpecific gravity in all parts, whether at the bottom, top, or middle of the maſs. To find out a natural ſolution for this phænomenon has, I dare ſay, ſtaggered metalurgiſts and philoſophers, eſpecially corpuſcular naturaliſts, who hold that matter was originally formed of impenetrable, indiviſible particles, of certain figures, ſizes and properties: for, were this the caſe, ſuch particles ſhould, in the preſent inſtance, take their orderly places, according to their reſpective ſpecific gravities. The expanſive power of fire having diſſolved their coheſion, overcome their attractions, and ſet them at liberty to obey the impulſe of gravity, nothing remained to hinder them from uniting in diſtinct homogeneous ſtrata, ſuch as nature had formed them in, when each compoſed a ſeparate body. The gold particles then, being of greateſt ſpecific gravity, ſhould all deſcend to the bottom, and there form a ſtratum of that metal; over them the ſilver particles, whoſe ſpecific gravity is little more than half that of gold, ſhould form a ſecond; and on the top the copper particles, whoſe ſpecific gravity is the leaſt of theſe three metals, ſhould form another diſtinct ſtratum. But the caſe is quite otherwiſe: for all the metals are found equally blended in all parts of the compound maſs. This is evidently the fact in our circulating money; for every guinea and ſhilling in the nation, as alſo the coin of every other country, is mixed with copper to harden the ſoft metals they contain. Boerhaave remarks the ſame of gold and ſilver, which blend ſo intimately, that if a grain of gold be melted with 100,000 grains of ſilver, it will be ſo equally diffuſed throughout all parts of the compound maſs, that, whatſoever part be taken thereof, will be found to contain both gold and ſilver in the above proportion. From this intimate mixture and union of metals ariſes the invention of *touching needles*, whereby deceptions in adulterated metals are detected.

But, however difficult it may be to explain this extraordinary mixture by attractions, corpuſcles, &c. it is eaſily and naturally accounted for by the help of our elaſtic matter. This ſubſtance has been proved to exiſt in all bodies, and diſplays itſelf moſt ſenſibly in elaſtic and ſounding bodies, as it is the ſource of both theſe qualities. Metals therefore are ſtrongly impregnated with it; and probably contain a ſpecies of it more denſe, than what inheres in moſt other bodies. When, therefore, the parts of different metals are intimately pervaded, opened and ſpread out by heat, their elaſtic matters come forth by expanſion, blend together, and mutually incorporate. Now, as theſe elaſtic matters are the ſource and ſupport of the powers and qualities, which characterize the nature of each metal, their union and confuſion unites and confounds all the qualities and natures of the ſeveral metals; for otherwiſe, theſe qualities ſhould either totally vaniſh, or elſe ſubſiſt without their adequate and ſupporting ſubſtances; the latter of which is contrary to our ſixth propoſition, and the former is falſified by the fact; for the qualities and natures of all the metals do not vaniſh, but remain in the maſs, and may, by chymical art, be again ſeparated and aſſorted, ſo as to reſolve the compound into its original and diſtinct metals.

It is therefore clear, that, when the different metals are opened and diſſolved in fuſion, their elaſtic matters, which are all of the ſame temperature and intenſity, being all in the ſame form, to wit, that of *mercury*, blend and diffuſe through each other, as would the different parts of the ſame homogeneous fluid, if variouſly agitated. It is likewiſe evident, that theſe elaſtic matters carry with them their reſpective natures and properties; ſo that the elaſtic matters being diffuſed through all parts, and univerſally blended, their reſpective natures and properties which adhere to them muſt alſo be generally diffuſed, and uniformly blended. Thus the whole, when in fuſion, becomes, as it were, one and the ſame fluid metal; and, when cooled, one homogeneous maſs, of equal ſpecific gravity, and uniform properties in all parts, bottom, top, and middle, through the mixture of the elaſtic matters, which, by intimately uniting, form a common vinculum for joining together qualities originally ſeparated, as the fact plainly atteſts.

Here it is to be obſerved, that the inert matter cannot produce the ſpecific gravities, or peculiar degrees of tenacity of different bodies, as well, becauſe this matter is the ſame in all bodies, as becauſe, by its nature, inert matter is void of qualities. Neither are theſe properties natural to light, which, on the contrary, is the ſource of levity and expanſion: an adheſive ſubſtance is therefore neceſſary to endow metals and ſtones with theſe properties; and from the various quantities of this third ſpecies of matter, may ariſe the different ſpecific gravities of bodies, and their different degrees of coheſion. From this matter alſo, contextured with light, the elaſtic matter of different bodies may derive its various degrees of denſity and ſpiſſitude.

From all theſe inſtances we may infer, not only the utility of the elaſtic matter in preſerving and enlivening the powers and qualities of bodies, as being their ſupporting ſubſtance; but even the neceſſity of this univerſal principle, for almoſt all the other operations of art and nature. It is uſeful, and even neceſſary for the tranſpoſition of powers and qualities from one body to another, by which common water is impregnated with nouriſhment, ſpirit, and various qualities, as in liquors, ſyrops, &c. By it qualities are again transferred, by a tranſlation of their ſupporting ſubſtance, from impregnated water to other ſubſtances, as colour in the dying of ſilk, wool, or cotton. This principle is alſo neceſſary to ſerve as a common medium, wherein matters of various kinds and ſpecific gravities, are reduced to an equilibrium; and to become a common vinculum for uniting and retaining all their qualities in one common ſubſtance, whether fluid or ſolid; as we have ſeen in brewing and decoctions, and in the mixture of metals. From the ſame uſeful principle we may collect the reaſon why gold is diſſolved, ſuſpended, and equally diffuſed through aqua regia, and why ſilver is ſimilarly affected by aqua fortis. Theſe phænomena are generally aſcribed to attraction; as are likewiſe the aſcent of the earth's juices in plants: this latter opinion philoſophers attempt to confirm and illuſtrate, by the aſcent of water in capillary tubes; although attraction has never been able to raiſe water to the top of a tube, whereas in vegetation, the juices muſt riſe to the top of the plant, in order to protrude a gem, and continue the riſing growth.

But doubtleſs this aſcent of juices in vegetation is occaſioned by the heat of the earth and ſun; otherwiſe, why ſhould vegetables be more vigorous, large and fruitful, in the torrid zone, and hot climates, than in cold ones? What ſhould be the uſe of hot-beds and ſtoves, but to ſtimulate action and motion in the elaſtic matter, on which depend the lively powers and qualities of bodies, and whoſe expanſion raiſes their juices, and extends their growth, when excited by heat; as appears by the effect of the ſolar heat during ſpring and ſummer?

The circulation of the blood, and the motion of the animal ſpirits, are alſo imputed to attraction; although nothing can be more evident than that every animal body has a power of expanſion, which propels perſpiration, excludes excrement, and which is not only capable, of producing the circulation of the blood, but of ejecting it forcibly, when a vein is opened, or a limb cut off. In ſhort, it is on this expanſive vigour, of which the elaſtic matter is the ſource, that the ſtrength, activity, and even the life of animals depend, as will appear from the following experiment, which is an imperial inſtance of the utility and univerſal neceſſity of this elaſtic principle.

Let a frog be ſtretched out, tied down to a board, and cut open, without wounding the heart; although the animal be killed by this operation, its heart will continue to beat, while it retains its native heat: but, on cooling, the beating will ceaſe, which indicates that the heart is likewiſe dead. Nevertheleſs, warm it with your breath, and its palpitation ſhall revive, and continue, until it again grows cold; when it ſhall again ſtop beating, and become torpid. Warm it a ſecond time with your breath, or if that ſuffice not, lay a drop of warm water upon it, which will again animate the heart, and renew its palpitation as before. Nor is a frog the only animal whoſe heart and nerves exhibit a lively motion after the death of the body. The parts of an eel, a ſerpent, and moſt other reptiles, when cut in pieces, will twiſt and move. The legs and wings of certain fowl will likewiſe work after the head is cut off: the fleſh of an ox or cow, while warm, will tremble and move for ſome time after it has been killed; all which motions are indications of an elaſtic principle in the parts, and have no relation to attraction: for, will any one pretend that the breath or water affects the frog's heart by attraction, and thus occaſions palpitation? Is it not rather heat, which we have already obſerved to give expanſive force to air and water, that now renews its beating? For cold water will have no ſuch effect; but as often as heat is applied, while the tone and ſtrength of the heart remain unhurt, the elaſtic matter it contains is ſtimulated to action, and forced to reſume its natural vibrations.

I have taken up a drowned mouſe, which was, or at leaſt appeared dead, the creature having lain ſtretched and motionleſs under water for the ſpace of ſome minutes. This animal I laid before the fire, and covered it with dry aſhes; in half a minute, the aſhes having imbibed the moiſture, formed a cake about it; I then removed them, and covered it anew with dry aſhes, over which I raked down ſome hot aſhes, to ſtrengthen the heat; theſe again caked as before, and were then removed. Having repeated this operation three or four times, the aſhes no longer caked, which gave room to conclude, that the redundant moiſture had entirely evaporated: I therefore left it in this ſituation, covered as before with hot aſhes, and waited for the event; after a while, the aſhes began to ſtir before its noſe, which ſeemed to work through, as does the bill of a chicken through the ſhell in which it gets life. At length the noſe advanced forward to the eyes, which cautiouſly peeped on every ſide, and the creature perceiving no enemy near, crept away from its cover; for I thought it a pity to deſtroy a life which I had taken ſuch pains to reſtore.

Drowned flies, which had lain in liquor, and perhaps been dead during an whole night, have been recovered by ſcraping on them duſt of chalk, ſo as to cover them all over; nor is it neceſſary to repeat this operation as it was in the foregoing inſtance. But if the mouſe had been dead even for an hour, or a conſiderable number of minutes, it is very ſuppoſable, that it could not be thus recovered; becauſe, in that caſe, the elaſtic matter of the heart, which is the fountain of life, would have removed from its place, and by its expanſive property have diffuſed itſelf equally through all parts of the animal and of the water, in which it was drowned, whereby the heart would loſe its tone, ſtrength, and elaſtic vigour, as not poſſeſſing more elaſtic matter than any other part: and if there were no means to ſend this matter back, and reinſtate it in the heart, it would be impoſſible to recover the animal; becauſe the fountain of life could not be repleniſhed with that active principle and ſource of motion. But while the heart is not deranged by any diſtortion or laceration, (ſuch as happens to animals that die in an exhauſted receiver) and ſtill retains a ſufficient fund of this active matter, it will, on the application of heat, (provided the moiſture, which ſhackled it down, be removed) expand and give motion to the heart; and the heart itſelf, being ſtill ſound, as we ſuppoſe, will operate regularly, and propagate its new revived ſpirits throughout the body, ſo as to renew all the animal motions, and reſtore life.

As to the continuance of the elaſtic matter in the heart for ſome time after the animal is killed, it appears evident from the motions excited and ſtimulated in the frog's heart by the application of heat. Nevertheleſs, the recovery of this animal was impoſſible on account of the ruin and derangement of other parts and members, through which the animal fluids ſhould circulate for the reſtoration or preſervation of life. But in the revival of the mouſe, all theſe parts and members remained entire; no tube or veſſel being cut, all retained their proper order, and mutual communication; ſo that as ſoon as the clog of moiſture was removed by evaporation, the fluids and ſpirits reſumed their natural circulation, being renewed by heat, and propelled by the motion of the heart. This motion was communicated to the heart by the action of the elaſtic matter, which was ſo rouſed by the heat the animal was expoſed to.

In the courſe of theſe explanations, we have ſtiled moiſture a clog upon the elaſtic matter, which ſhackles it down, and reſtrains its activity. The truth of this aſſertion is apparent from the power of water in extinguiſhing fire, and diminiſhing heat: for if wet cloaths be ſet to dry in a ſtove or bagnio, the heat will be thereby ſenſibly reduced. Fruits of any kind rared in a moiſt climate, are not ſo aromatic or ſavoury as thoſe rared in a warm or dry climate; and even thoſe produced in the ſame climate are found very different in taſte and flavour, according as the ripening ſeaſon has been wet or dry.

Hence we ſee the effects of Noah's flood on the productions of the earth; for the elaſtic matter of the earth being repelled and reduced by the waters of the deluge, for ſome diſtance below the ſurface, her fruits and productions could not be ſo rich and vigorous after the flood, as they had been before: conſequently, animals muſt have alſo degenerated and partaken of the laſſitude which took place in vegetables, when deprived of the elaſtic matter, the ſource of their ſpring and vigour, this may likewiſe be the phyſical cauſe, why the Poſtdilluvians are not ſo robuſt, vigorous, or long-lived as the Antedilluvians were.

LECTURE V.

An Hiſtory of Fire. The Elaſtic Matter identified with that Subſtance, with Newton's Ether, and with the Electric Matter.

◆

SECTION I.

Fire in the Earth, and in all its Productions.

WE have, in the courſe of the two preceding Lectures, traced elaſticity through all the bodies in nature. We have alſo explored its cauſe, and found it to be an elaſtic matter, ſpecifically diſtinct from inert matter. The diſtinction of theſe two ſpecies of matter we have exhibited in their union and ſeparation; as alſo, in the tranſpoſition of the elaſtic matter from body to body, whereby the qualities of one body were ſuperinduced upon another, along with this active principle, the baſis of all powers and qualities. To diſcover more fully its intimate nature, we ſhall, in this Lecture, lay down a ſhort hiſtory of fire. But firſt we ſhall add to thoſe already given, a conciſe proof that the elaſtic matter inheres in, and enters into the compoſition of every body in nature. All philoſophers, and the learned in general, agree, that air is endowed with an elaſtic principle; this opinion has been repeatedly corroborated in our two foregoing Lectures: but the illuſtrious Boyle was the firſt, who made this further diſcovery, *viz.* that an elaſtic matter in air is the baſis and ſupporting ſubſtance of its repulſive and elaſtic powers. If therefore, as experience proves, and philoſophers affirm, air enters into the compoſition of all bodies whatſoever, it follows, that this elaſtic matter, inherent in air, is blended with every other body. The ſame concluſion we have already drawn from the inveſtigation of numerous operations and effects, which fall within every man's cognizance and experience. It would be tedious to repeat the ſame proofs here, they may therefore be examined in their places.

Chymiſts diſtinguiſh various ſorts of what they call factitious or artificial airs, to wit, the fixed, the mephitic, the inflammable, the nitrous, the acid, the alkaline, and the phlogiſtic air. Doctor Prieſtly ſays, fixed air is unelaſtic, and to be found over fermenting liquors, and alſo in chalk, marble, and ſuch calcarious bodies. Now that air ſhould be able to ſeparate itſelf from the parts of the body wherein it is by nature contextured, and at the ſame time be non-elaſtic, is rather paradoxical; but diſtinctive names for theſe airs are uſeful. The term *mephitic*, is uſed to denominate ſuch airs as are noxious to animal life, as that of ſulphur and charcoal; ſulphur however, gives name to an air extracted from bodies of that nature, as the air obtained by means of a nitrous ſpirit, is called *nitrous* air, and that from ſalts or acids, is *acid* air; that gained from inflammable bodies is *inflammable; alkaline* air is that extracted from vegetables. Thus philoſophers find, by their minute enquiries, that every body produces an air peculiar to its predominant nature, although all thoſe kinds of air have but one elementary principle; which is an experimental proof of what we have advanced in our laſt Lecture, to wit, that air and light are accretive ſubſtances, which give vigour and magnitude to growing bodies, but which are ſomewhat changed from their elementary form, and aſſimilated by the Divine efficacy of the Creator's law, to the peculiar nature of the body, to whoſe compoſition they accede. And doubtleſs, if they were not endowed with this aſſimilating faculty, the bodies moſt different in kind, in the ſucceſſion of ages, from an accretion of the ſame elementary matters, would degenerate into one and the ſame kind; in which caſe, we ſhould not this day enjoy that admirable variety of beings, ſo different in nature and properties, which is diſplayed throughout the univerſe.

It is on account of this natural power of aſſimilation, with which the Creator has endowed all bodies, and which we plainly diſcover, at leaſt, in all growing bodies, that the elementary matters, fire, air, and earth, are found in all compound bodies, but variouſly modified. However, whatever changes theſe elementary matters undergo, can never deprive them of their reſpective eſſences; for we have proved that the eſſence is inſeparable from its ſubſtance: conſequently, as we have ſeen that the elaſtic matter is the baſis, and conſtitutes the eſſence of air, no air, however charged, or infected it may be, can be ſuppoſed un-elaſtic, but more eſpecially, when ſuch air is produced and ſeparated from its native body by the exertions of its elaſticity.

Fire may now perhaps be made appear as univerſal in nature as air, according to the opinion of Boerhaave; for, although it be latent and dormant in moſt bodies, yet when excited and urged to come forth, it ſoon diſcovers itſelf, either by *heat*, *light*, or *expanſion*, which are the characteriſtics of fire, as the ſame learned chymiſt collects from his indefatigable reſearches after fire, and its properties. Of theſe three properties, expanſion he declares to be the moſt conſtant and inſeparable characteriſtic of fire; for, while he finds light without heat, and heat without light in body, either, or both are always accompanied with expanſion, which, according to Sir Francis Bacon, is the eſſence of fire. The following Lemma will obviate difficulties, and facilitate our inveſtigations on this ſubject:

LEMMA,

A thing, or the natural ſign of a thing, coming from a body or place, is an actual and rational proof that ſaid thing was, or is reſident in that body or place.

Otherwiſe effects would not be a guide to their cauſes, and experiments would be uſeleſs in philoſophy. The converſe however of this rule is not ſo eaſily to be admitted; ſo that tho' evidence force us to conclude, that fire exiſts wherever its natural ſigns are diſcovered, yet our deference for the well-grounded opinion of Boerhaave, will not allow us to adopt a contrary perſuaſion, where we do not immediately diſcover theſe characteriſtics. Sometimes we ſhall meet bodies, which, though urged in every manner, exhibit none of theſe characteriſtics; however they are not to be pronounced deſtitute of fire: for, if their qualities and powers are found to be improved, ſtrengthened, and revived by fire, it is natural to ſuppoſe, that the ſame powers and qualities are nouriſhed and preſerved in the body by its innate fire, however latent it may be.

Few would attribute fire to lead, yet, on being hammered, it becomes warm, which is a ſign of its innate fire. Neither would a ſtranger to the effects of gunpowder attribute fire to it, for it ſhews neither elaſticity, heat, nor light, until touched by a ſpark; but then it diſplays theſe characters of fire in a prodigious degree: whence, by our Lemma, we have a certainty that fire is inherent therein. Gunpowder muſt derive its fire from the fire of its ingredients, which are ſulphur, nitre and charcoal, and perhaps from air and light. Sulphur is a foſſil ſubſtance, replete with fire perfectly latent, until it be touched by a ſpark; it is therefore the chief combuſtible uſed in the the preparation of fire-ſhips. Lead, with moſt metals and ſemimetals, contains its ſulphurs, for which reaſon, they all exhibit ſigns of fire when properly urged.

Nitre is not ſo much a foſſil, as an exuberance in old walls, and in the earth, exuding, according to Boerhaave, from the ſurrounding bodies. Its origin is as yet the object of conjecture. But it has a very expanſive power, and is therefore employed in gunpowder and fire-ſhips. The wood whereof charcoal is made, is a good kind of fuel, which, in burning, affords heat, light, and a ſtrong flame. Two pieces of this wood, when dry and hard, if rubbed together, will firſt grow warm, afterwards turn black, and then kindle. This is a reſource amongſt the American Indians, which ſupplies the want or ignorance of flint and burning-glaſſes.

It is well known, that a well ſhod horſe in trotting, will ſtrike fire out of ſtones. Steel will produce the ſame effect on flint, as will a ſmart ſtroke of an hammer upon any kind of ſtone or hard metal, upon loaf ſugar, and ſeveral other ſubſtances. Theſe effects are in general only diſcernible in the dark; ſometimes indeed they become perceptible in the light, by kindling gunpowder or other combuſtibles. Timber and ſoft metals, when their interior fires are excited by friction, are likewiſe capable of inflaming ſuch combuſtibles. It were to be wiſhed we could thus derive from experience, ſome intelligence reſpecting ice; for the conſtant reports of experience, taken from the common and uſual operations of nature, are more ſolid and ſatisfactory grounds than any particular experiments, which, however, are often the foundation of a theory. All theſe bodies have a reſtitutive power, which is diſcoverable by the pendulous teſt: they have alſo the faculty of producing ſound, which is another proof of their elaſticity, and even of their containing fire, as we ſhall now ſee.

When two pieces of dry wood, or any other hard elaſtic bodies, are rubbed together for a while, with a preſſive force, and a quick motion, the tremours and vibrations of the parts will warm the bodies, and excite motion in their elaſtic ſpecies, towards the fricted ſurfaces, where the ſpecies, crouding and acting on itſelf, cauſes heat. This heat, if the rubbing be continued briſkly, will ſtill increaſe, by the conſtant flow of the ſpecies to the ſurfaces; at length, when a quantity of it is collected on the rubbing ſurfaces, if the bodies employed be wood, the ſpecies nouriſhed by this fuel, agitated by its own claſh, and fanned by the air, will kindle into fire or flame; to prevent which, the naves and axles of coaches, carts, mills, and other machines, are greaſed, to diminiſh their friction, or frequently wetted, to prevent inflammation.

This explanation of the origin of flame, may be confirmed by this obſervation. A red coal, if ſet alone on the hearth, will ſoon grow black and extinguiſh; but if laid cloſe to another equally hot, the fire at their touching ſurfaces will continue, and riſe to a flame, while, on the other ſides, it will ſoon die away; which ſhews that the oppoſing efforts of the fiery ſpecies thus meeting, and acting againſt each other, enliven and preſerve their mutual vigour. Juſt ſo, in the foregoing experiment, the elaſtic ſpecies being agitated, and excited to greater vigour by its conflict between the fricted ſurfaces, produced heat and flame. If the bodies were not of the fuel nature, their friction would not occaſion flame: hard bodies indeed, by a ſmart ſtriking or rubbing together, will emit ſparks, but ſoft ones will only heat, or grow warm.

The effect produced by a ſudden ſtroke, is ſomewhat different; for, in this caſe, the elaſtic ſpecies of the ſtriking bodies ſprings to the point of conflict, where by the claſh of the elaſtic matter, flame is produced, often ſo intenſe, as to vitrify the ſhivered particles, and make them fly off in glowing ſparks; as, for inſtance, upon the colliſion of flint and ſteel. Similar to this, is the effect, of which a perſon is ſenſible, who receives a ſmart blow upon the eye; for he thinks on the occaſion, that fire is ſtruck out of it, the ſenſibility of that organ correſponding with the velocity of its object. When a perſon ſhuts his eye, he has the ſenſation of a dark medium, filled with atoms of a dim light, and in a confuſed motion: the eye being then preſſed, the darkneſs in one part diminiſhes; if the preſſure is increaſed, that part becomes brilliant, as if the lightſome particles were there collected, and ready to flaſh out, were the impreſſion more violent, like that of a ſtroke.

The reſemblance between theſe ſenſations, and the phænomena obſerved on the friction or colliſion of hard bodies, ſhews a vaſt affinity between the ſpecies of light in the eye, and the elaſtic ſpecies of theſe bodies; and induces us to think they are one and the ſame thing in ſubſtance and eſſence: for the ſame cauſes produce in both the ſame effect, and follow the ſame mode of operation; therefore, according to the rules premiſed, their principles, that is, their ſubſtances and eſſences are the ſame. We are likewiſe to take notice, that electricity is excited by rubbing, whereby an electric fluid is collected in the fricted body, and emanates ſo copiouſly and potently, as to agitate a feather, leaf-gold, and ſuch light bodies, at the diſtance of ten or twelve inches. The ſame fluid will ſtream from a point of the impregnated bar, with ſuch repulſive force as to turn a wheel rapidly, and in the dark to appear a luminous flame: all which phænomena agree again with thoſe already compared, relative to the eye and the fricted bodies. There is this one difference, that the electric fluid is excited by rubbing an hard and ſoft body together; whereas fire is excited by rubbing together two hard bodies. But this difference in the agents, produces a correſponding difference in the effects; for the hard bodies by their friction, excite a ſtrong flame, while the hard and ſoft, excite but a ſoft mild flame. And this diſtinction is again oppoſed by a new reſemblance; for the bodies which produce the electric fluid muſt be dry and elaſtic; as muſt alſo theſe which produce flame.

Again, it ſeems that this common principle of elaſticity and electricity in bodies is alſo the ſource of their fires; for in electric experiments, the electric fluid, which turns a wheel, will in the dark appear to be a bright flame: now, if like effects ariſe from like cauſes, the fires already mentioned, generated by the colliſion and friction of bodies, muſt ariſe from their elaſtic matters; and therefore the elaſtic matter of bodies is the ſource of their fires. We have ſeen that ſtones, metals, and in general, all bodies exhibit ſigns of their innate fires, by colliſion, or friction; we know alſo, that coal, and other foſſils, ſerve for fuel in many countries; other nations employ wood and vegetables for the ſame purpoſe; all countries in ſhort, are ſupplied with fire from the ſurface or interiour parts of the earth: ſince therefore, fire is found in every part, the whole earth muſt be replete therewith.

This concluſion is again evident from the vulcanos that ſurround the globe. Veſuvius in Naples, Ætna in Sicily, and Hecla in Iceland, are in the moſt ſouthern and northern parts of Europe: there are others in different parts of Aſia, Africa, and America, which ſhew clearly that the whole earth is full of its fires, and combuſtible matters.

The expanſive force of gunpowder does not point out the eſſence, and predominant power of fire ſo conſpicuouſly and tremendouſly, as the phænomena of vulcanos and burning mountains. "A vulcano," ſays Doctor Goldſmith, "may be conſidered as a "cannon of an immenſe ſize, the mouth of "which is often near two miles in circumference. From this dreadful apperture are "diſcharged torrents of flame and ſulphur, "and rivers of melted metals; whole clouds "of ſmoke and aſhes, with rocks of enormous ſize, are diſcharged to many miles "diſtance; ſo that the force of the moſt "powerful artillery is but a breeze agitating "a feather, in compariſon."

In Japan and its adjacent iſlands, are ſeveral burning mountains. They are alſo found in Java, Sumatra, and other of the Phillippine and Molucca iſlands. There are numbers in Mount Taurus, and other parts of Aſia. In Africa, the iſland of Delfugo, and the Peak of Teneriff, are conſtantly burning. But of all parts of the earth, theſe dreadful operations of nature are moſt conſpicuous in America; Veſuvius and Ætna are but fireworks in compariſon to the burning mountains of the Andes, which are at the ſame time the higheſt mountains in the world, and the moſt formidable for their eruptions.

The violent eruptions of theſe vulcanos are evidently occaſioned by, and univerſally aſcribed to, the exploſions of the ſubterraneous fires, wherewith the earth is every where replete. The expanſive power of theſe ſubterraneous fires, and their efforts to explode, are alſo allowed to be the cauſe of earthquakes, which ſpread whole countries with ruin and deſolation. Both theſe phænomena are ſtriking, but fatal inſtances of the expanſive force of fire. Vulcanos however are far the leſs formidable, as their effects may be foreſeen, and being confined to ſtated places, are eaſily avoided: they may even be conſidered as uſeful; for they ſeem to be ſo many chimneys or vents, formed by Providence to diſgorge theſe burſting fires, and ſo prevent earthquakes, which ſhould otherwiſe ariſe from the tremours, heavings, and exploſive efforts of the expanſive matters emboſomed in the earth. For theſe expanſive matters, when excited by friction, colliſion, or fire, whether they burſt from their bed in a perpendicular direction, or range in conflagration through the caverns of the earth, find vent through thoſe right or oblique fiſſures, called *vulcanos*; and by iſſuing forth, ſpend that force, which, if confined, would produce tremendous earthquakes. Theſe remarks are verified by a recent event, the knowledge of which we owe to the curioſity of Sir Richard Hamilton. During the late earthquakes in Calabria, the eruptions of the vulcano Strombolo, were obſerved greatly to abate; but, when the eruptions recommenced with their uſual violence, the earthquakes ceaſed, becauſe the inflammable matters had then returned to their native channel.

The concomitant circumſtances of theſe laſt ſtupendous effects, are a further proof of what we here advance. They are thus deſcribed by Goldſmith. "A rumbling ſound,—a violent agitation of the ſea,—a ſpouting up of waters to great heights,—a rocking of the earth to and fro, and ſometimes a perpendicular bouncing," &c. Theſe are all clear indications of the expanſive force and vigour of ſubterraneous fires, and make the earth ſeem a kind of bomb, or body filled with exploſive combuſtible matter. Sir William Hamilton, in his account of the earthquakes in Calabria, which happened in 1783, relates, that a great number of towns, villages, and farm-houſes of that province, were totally ruined by the firſt ſhock on the 5th of February; and the more diſtant ones were greatly damaged by the ſubſequent ſhocks of the earthquakes, on the 7th, 16th, and 28th February, and on the 1ſt of March, during which time, the earth was in a continual tremour, with alternate ſhocks at different times and places; that many openings and cracks had been made within that ſcope, ſome hills lowered, others quite levelled, deep chaſms made in the plains, which rendered the roads impaſſable, huge mountains ſplit aſunder, and great parts of them driven to a conſiderable diſtance. He relates, that in Calabria Ultra, the ſurface of two whole tenements, with large olive and mulberry trees therein, ſituated in a valley perfectly level, had been detached by the earthquake, and tranſplanted, the trees ſtill remaining in their place, to a great diſtance from their firſt ſituation; and that from the ſpot where they formerly ſtood, hot water had ſprung up to a conſiderable height, mixed with ſand of a ferruginous nature. He was aſſured that the vulcano Strombolo had ſmoked leſs, and thrown up a leſs quantity of enflamed matter during the earthquake, than it had done for ſome years paſt. He tells us, that although the object of his preſent journey was merely to view the ſpots which had ſuffered by the calamity, his attention was continually called away and loſt in the admiration of the fertility and beauty of this rich province, exceeding by many degrees, as to fruitfulneſs, every country he had ſeen. Beſides the two rich productions of ſilk and oil, in which this province ſurpaſſes every other country perhaps in the whole world, it abounds with corn, wine, cotton, liquorice, fruit, and vegetables of every kind, and its population and induſtry, kept pace with its fertility. Hence we ſee that the earth is naturally provided with ſtoves and hotbeds, or is rather itſelf one univerſal hotbed, to accelerate vegetation, and force up the juices to the tops of plants and trees, be they ever ſo high; while to raiſe the juices to the tops of capillary tubes, is beyond the power of attraction. Thus we find fire in every part and production of the earth. It every where diſcovers itſelf by its ſenſible qualites, but more particularly its expanſion, which, according to all philoſophers, is the very eſſence of fire.

SECTION II.

Fire traced through Water and Air.

AS water extinguiſhes fire, and ſeems to be of an oppoſite nature, it may appear ſtrange to carry into this fluid our reſearches after fire. But, although we cannot here exhibit it as ſenſibly as in the earth and its foſſils, we ſhall ſhew its characters ſo conſpicuouſly, as, according to our Lemma, to eſtabliſh its reſidence there, and corroborate Boerhaave's aſſertion, that *there is not a body in nature deſtitute of fire.* We have proved in the preceding Lectures, that water incorporates much of the elaſtic matter there mentioned; and have ſhewn this ſubſtance to be the ſource of its undulating power, and diffuſive force. Theſe qualities have a great affinity to expanſion, the eſſence of fire; but as a ſingle property is not a ſufficient foundation for a general concluſion, we ſhall now exhibit the other characters of fire.

Sailors affirm, that during dark nights, when neither moon nor ſtars appear, without ſtreamers, fire-balls, or any other meteors, they perceive ſhips or rocks at ſuch a diſtance, as to be able to change their courſe, and avoid danger. Now as it is impoſſible to ſee without light, we muſt conclude, that the medium of viſion here emanates from the water, and thus affords a ſign of the fire there contained, and even a more ſenſible one, than wood or ſtone will exhibit, unleſs they are urged by friction or colliſion. Theſe operations require a coheſion and elaſticity of parts inconſiſtent with the nature of a fluid; as far however as friction is applicable to water, it will diſcover the fire there latent.

In a ſtorm, when the waters are deeply agitated, and the ſwelling waves fall with a violent laſhing on the ſurge beneath, the latent fire, rouſed by the conflict, diſplays itſelf to view; for, while the heavens are wrapped in darkneſs, the horizontal ſcope is illuminated with gleams of light, which iſſue from the broken waves, and ſhew the horrors of the ſcene. Light then ariſes from water, when excited by friction, or colliſion, as it does from hard bodies; ſhould not the principle therefore be the ſame in both, when the operations and effects are the ſame?

It will perhaps be objected, that heat makes a difference; for beſides light in hard bodies, friction produces heat, which has not been obſerved in the foregoing inſtance. But the report of Captain Phibbs removes this difficulty; for, on his return from the North Pole, whither he ſailed to explore the north-eaſt paſſage, entering the German Ocean, he met with a ſtorm, whereupon he was ſtruck with a curioſity to know, if the agitation of the ſea excited heat, as it was known to produce light. To make the diſcovery, he ordered water to be taken up from various depths, into which having plunged the thermometer, he found the ſpirits roſe ſeveral degrees; which ſhews the agitation of the waters had produced in them an heat greater than that of the atmoſphere. Now as they received not this heat from abroad, it muſt have been the effect of their own innate fire, enlarged and actuated by the motion of the waves.

The ſame effect, though leſs ſenſible, is experienced by thoſe who are accuſtomed to bathe, for they find that the water when thus agitated, wants much of the piercing cold they feel in it when calm and ſettled. We ſee in the ſame manner, the churning of milk makes it warm. Heat then, as we have ſaid before, is excited in fluids, as well as in hard bodies, by friction. If then ſuch excitation be a proof of fire in the one, the ſame inference ſhould be drawn with regard to the other; and water, which joins a ſenſible heat with ſuch a profuſion of light, muſt be allowed to contain the principle of both, which is fire, and partake of its eſſence, which is expanſion.

We have, in the foregoing Lectures, proved the exiſtence of the elaſtic matter in water; we have alſo ſhewn that this matter is the ſource of powers and qualities, but of expanſion in particular. Expanſion we hav again obſerved to be the eſſence of fire; when therefore water, or any other body, exhibits this property, (without recurring to our Lemma) we ſhould conclude it contains fire, to which this property eſſentially belongs.

Now the round eaſy curl of the watery ſurge, the ſwell of its waves, with their ſound and roar, are the effects of expanſion. The circular waves that are ſucceſſively generated by the ſingle plunge of a ſtone, the ſteadineſs of a feather or chip, which continues in the ſame place, while thoſe circular waves paſs and expand themſelves under it, and the diffuſion of theſe waves, even againſt the ſtream, are likewiſe owing to expanſion. The long continuance of the ſwell and roar of the waves, after a ſtorm has ceaſed, their often riſing and rolling without any wind to excite their motion, like the atmoſphere, which is often thrown into perturbation by latent cauſes, all theſe effects, I ſay, invariably proceed from the ſame cauſe, to wit, expanſion.

If expanſion be not the cauſe of theſe effects, what other principle ſhall we aſcribe them to? We know no other, except attraction or gravitation, both of which, according to the idea we have of their power, are inconſiſtent with theſe phænomena; for the power of the one is to bind things together, and of the other to bear them down to the centre of the earth: if then theſe two were the predominant, I ſhall not ſay the ſole principles in water, how could ſo many circular waves ariſe after the ſingle plunge of a body into water, or diffuſe themſelves ſo widely? Gravity would oppoſe the one, and attraction prevent the other; and both would oppoſe that ſwelling and perturbation of the waves, which outlives, and ſometimes precedes a ſtorm. Far from having ſuch phænomena without wind or tide, if gravity and attraction were the chief agents in water, both wind and tide ſhould be very powerful, before any ſuch phænomena could ariſe; for, in all caſes, cauſes muſt be adequate to their effects, and effects to their cauſes, otherwiſe farewell to philoſophizing by ſyntheſis, analyſis, experiment, or analogy.

We ſhall now purſue our hiſtory of fire through air; for this purpoſe, we need not aſcend to the upper regions of the univerſe, ſince every burſt of thunder ſeems to fill our atmoſphere with flame and lightning, all the effects of which are ſo many proofs of its elaſtic force. Its devaſtations upon animals, vegetables, and the earth itſelf, with its tremendous roar, are dreadful inſtances of elaſticity; and that glow that fills the atmoſphere from a ſingle flaſh, clearly exhibits the eſſence of fire, *viz.* expanſion.

The electric fire, collected from a thunder cloud, the Aurora Borealis and Auſtralis, and other ſtreamers (which in the frigid zones, and other high latitudes, ſeem to ſupply the abſence of the ſolar light and warmth) fire-balls, and all the variety of fiery meteors, are glaring proofs of real fire in the heavens; and when taken together, ſeem to confirm the opinion of Boerhaave, that the atmoſphere is the great magazine of all our light, heat, and fire, which are only directed to us by a power in the ſun. This opinion was originally broached by the younger Lemery, another eminent chymiſt of the laſt century, not far inferior to Boerhaave, who ſtands unrivalled in that ſource of experimental knowledge. His opinions therefore deſerve the utmoſt deference, particularly in a treatiſe where the principles and powers of nature are inveſtigated, amongſt which fire holds the moſt conſpicuous place.

It is evident, this great chymiſt made fire the peculiar object of his enquiries, from the ſtreſs he lays upon its influence and operations. Without it, he declares, there never has been nor can ſubſiſt, a chymical operation. It is, he ſays, on account of its prodigious power, extenſive effects, and ſurpriſing mode of acting, that the wiſeſt nations of old worſhipped fire as the Supreme Deity. He makes it the principal cauſe of almoſt all the ſenſible effects that fall under our obſervations; but remarks, that it is of ſo ſubtile a nature, as to elude the moſt ſagacious enquiries; whence, by ſome it has been looked upon as ſpirit rather than body. We ſhall therefore take into conſideration his opinion on this ſubject. The ſun is univerſally conceived to be the fountain of heat and light, and the great magazine where the Creator ſtored up fire for the purpoſes of nature. This opinion however, both Boerhaave and Lemery oppoſe; the former delivers his ſentiments in the following words, (vol. 1, page 150) "I have been a great while in doubt "whether I ſhould venture to publiſh an opi-

"nion which I have long revolved over and "over in my own mind. It ſeems probable "that the ſun does not, in reality, emit any "ignious matter, to which we can aſcribe "any of the actions of fire that fall under our "obſervation; but that it has only a power "of determining the pre-exiſtent fire into "parallel right lines, without making the "leaſt addition thereto," &c.

This opinion, when properly conſidered, will appear as unphyſical, as it is ſingular; for, ſince we ſee that the light of a candle waſtes, and entirely exhauſts the tallow or wax that ſuſtains it, that it cannot ſubſiſt longer than while it is nouriſhed and preſerved by ſuch food; that all fires we are acquainted with, require a fuel or *pabulum* to ſupport them, and to ſupply the loſs they ſuſtain by their effuſions of heat and light; we muſt conclude by analogy, that the light and heat we perceive coming from the ſun, are really part of his ſubſtance, as the heat and light now mentioned are of the candle, or culinary fire. We muſt alſo, by the ſame rule, conclude, that the ſun is conveniently provided with an inexhauſtible ſtore of food to ſupply the loſs of ſubſtance he has ſuſtained by his conſtant effuſions of heat and light, for near 6000 years already elapſed, and which he ſhall ſuffer during the remainder of his exiſtence.

If comets were the only fuel and food deſigned for this purpoſe, they ought at the beginning to have been more numerous than the ſtars, and ſhould approach him more frequently than once in ſixty or an hundred years; for there are good reaſons to ſuppoſe, that a comet would ſcarcely ſupply the waſte he ſuffers in the courſe of one year, or perhaps of a day. This we ſhall hereafter take into conſideration; and if we find not food more adapted, and ſufficient to preſerve his magnitude and vigour, (which, by the way, ſeem to be permanently the ſame) we muſt ſubſcribe to this, or ſome ſuch ſingular opinion; for the preſent, however, we ſhall not be backward in expoſing its difficulties, and bringing it to the teſt by the phænomena of the planets, and celeſtial obſervations.

The atmoſphere, according to this great chymiſt, is the magazine of what he calls *pre-exiſting*, fire; but, according to our conceptions, it only contains a portion of that light, which the Creator made and blended with the chaotic matter, to warm, enliven, and prepare it for the intended productions. To explain this notion, all the luminous matter originally created, we conceive to have been thus diſpoſed of; one part was blended with the primordial matter, to fit it for the formation of terreſtrial bodies, which we find to be all compound; of theſe the atmoſphere is the moſt extenſive: it therefore contains a conſiderable portion of this light, interwoven with the other elementary matters, and thereby condenſed and confined in it, in the form of Boyle's elaſtic matter, a ſubſtance, ſince his time, little obſerved or inquired into. The remaining part of the luminous matter the Creator collected into the bodies of the ſun and ſtars, which were thus formed as ſtores of light for the ſucceſſive exigencies of their reſpective ſyſtems of planets, and the general purpoſes of nature.

Boerhaave, on the contrary, ſuppoſes that the ſun only has a power of determining the light of the atmoſphere in parallel lines; ſo that he directs it to us, while above our horizon, but when ſet, directs it to our Periœci, Antipodes, &c.

Now according to this hypotheſis, the inferior planets could not be obſcure in their inferior conjunctions, horned before and after, or appear as black ſpots on the ſolar diſk. The moon, in a ſolar eclipſe, would not appear as a dark body paſſing over the ſun: ſhe would not, in this ſuppoſition, be obſcure in conjunction, or appear horned between that and her quadratures: for the atmoſphere being a magazine whoſe latent fires the ſun blows up to give us light, it ſhould enlighten all things that are in, or near the line between us and the ſun; now all theſe planets are ſo ſituated in, or near their inferior conjunctions: conſequently, Venus and Mercury ſhould, in this poſition, be brighter than in the ſuperior conjunction, or even than the ſun himſelf, being there nearer to the ſource of light; for the atmoſphere, and not the ſun, in that ſuppoſition, is the luminous body.

The moon alſo, in the ſame poſition, ſhould appear as bright and full as in oppoſition: for, when a luminous body is between us and an opake body, the ſide of both which is next us, is illuminated; and the nearer the opake body approaches to us, and to the intervening light, the brighter it will appear. All this may be illuſtrated by holding an ivory ball on the different ſides of a candle, whence it will immediately appear, that the opake bodies mentioned, whether they regard the ſun or the earth as the centre of their motion, ſhould be moſt bright and conſpicuous, when between the ſun and us, being then on the other ſide of our luminous atmoſphere, and neareſt to its influence, and alſo to us. How then ſhould we have the phænomena of ſolar eclipſes, or the tranſits, obcurations, and horns of Venus, Mercury, and the moon, which attend thoſe conjunctions? From the impoſſibility of theſe appearances, we muſt conclude that the opinion of thoſe learned authors is intirely erroneous: we muſt however do them the juſtice to ſay, that the attempt, although it failed of ſucceſs, was a proof of their great phyſical knowledge; for they ſeem to have been driven upon this hypotheſis, by a true conviction, from univerſal obſervation, that no fiery body in nature can ſubſiſt without fuel or food to ſupply its effuſions, a remark which has not been ſufficiently attended to by more modern philoſophers.

After ſo obvious a confutation of this uncommon ſyſtem, it is unneceſſary to aſk theſe gentlemen, what conception can be formed of the ſun's nature and formation, to explain this power of determining the light of the fiery ſpace between him and us, without any emiſſion of his own ignious matter: for inſtance, if we are to ſuppoſe that he determines the intermediate fires as a mirror does light. But there is this difference, that light really exiſts previous to the action of the mirror, whereas the fires in queſtion are latent, and afford no light until they are excited and actuated by the ſun. Muſt we then imagine the ſun compoſed of an infinity of bellows fixed in his body, with their pipes out on his ſurface? But here we want a perpetual ſupply of air, and a principle of action, to diſtend and contract their dimenſions. Are we then to conceive him as reſembling a bell, and determining the courſe of light in all directions, as a bell by its undulations and vibrations propels and propagates ſound? In this caſe, he ſhould be furniſhed with an enormous clapper, and a force to perpetuate its motion. Finally, if he be ſuppoſed to excite and whiſk up heat and light by revolving about his axis, he ſhould be equipped with wings or whiſks ſtretched from his body, of a ſize proportionable to his bulk, and to the diſtance to which his operations extend. In order to ventilate fire at the diſtance of Saturn, their length ſhould certainly, in the plane of that orbit, exceed the diameter of the ſun, and being more conſpicuous than Saturn's ring, ſhould have been obſerved by aſtronomers, long before that diſcovery was made.

The ſun therefore, muſt be a luminous body, endowed with its own heat and light, and conſequently compoſed of fire. How immenſely great muſt be his expanſive force, to propel heat and light to the earth, and to Saturn, which is ten times farther off! His nature and fuel we ſhall hereafter endeavour to inveſtigate; for doubtleſs the Creator has provided large ſtores to ſupply the conſtant waſte he ſuffers by his prodigious effuſions of ſubſtance; and here we ſhall terminate our hiſtory of fire, which we have traced from the earth and its atmoſphere, to the ſun, the great fountain of heat and light.

SECTION III.

The Elaſtic Matter proved to be the ſame with Newton's Ether, with Elementary Fire, and with the Electric Matter.

SIR Iſaac Newton, after finiſhing his *Principia*, and his experimental piece upon optics, which were the chief part, if not the whole of his works upon nature, finds an elaſtic medium neceſſary in all parts of ſpace, to produce and preſerve the lively operations of body, whether hard or fluid. In the 19th query, at the end of his optics, he calls this matter an etherial medium, which, he ſays, is exceedingly more elaſtic than air, pervades all bodies, and is diffuſed through the heavens, vacuum, and all parts of ſpace. Its tremours and vibrations, he affirms, are ſwifter than light, which is accelerated, retarded, tranſmitted, and reflected by its operations. The ſame etherial medium he makes the ſource of thoſe waves that ariſe in water where a ſtone is plunged, likewiſe of the waves and tremours that ſpread on all ſides in air, from the ringing of a bell, and waſt the ſound in all directions. By its vibrations alſo, viſion and other ſenſations are produced; it gives free motion to the planets, and, in ſhort, is the cauſe of all the lively motions in nature, (ſee from the 17th to the 25th query) yet he confeſſes he knows not what it is; but in order to gain it eaſy belief and admittance, in his 22d query, he exhibits the power of magnetiſm, which pervades the hardeſt bodies; and of electricity, which, though imperceptibly ſubtile, will agitate leaf copper, and leaf gold, to the diſtance of a foot from the electric body.

Firſt then, if we compare the elaſticity of this ether, which the great Newton at the ſummit of his knowledge, conceived neceſſary for the operations of nature, if, I ſay, we compare the elaſticity, expanſion, and tremours of this ether, with the qualities of our elaſtic matter, which we have proved to be the cauſe of theſe operations, and ſhewn to be the baſis of air, conceived by the clear-ſighted Boyle, in which its ſpring and vigour eſſentially conſiſt, it will appear to every perſon verſed in the laws and method of philoſophizing, that Boyle's baſis of air, Newton's ether, and our elaſtic matter, are one and the ſame thing, under different appellations; otherwiſe two or more cauſes muſt be admitted for carrying on the ſame operations, and producing the ſame effects, which is contrary to the ſimplicity of nature; and to admit in nature more cauſes than effects, is likewiſe contrary to reaſon.

Secondly, in our preſent Lecture we have traced fire through all the bodies in nature, and diſcovered it wherever any degree of elaſticity was diſcernible, and we have found its eſſence to be expanſion. Boerhaave agrees with us in both theſe points; he affirms, that fire ſubſiſts in every body and place in nature, and pronounces its eſſence to be expanſion. The learned and inſtructive Bacon likewiſe, has traced fire through a variety of bodies, and compiled an hiſtory of its effects, and ſenſible qualities, with an intention to diſcover its *form* or eſſence. For this purpoſe, he reduces his hiſtory of fire to orderly tables of approximation and excluſion, and finds the *form* he ſought to be expanſion; hence he defines heat to be *an expanſive bridled motion, ſtruggling in the ſmalleſt particles of bodies.* So that theſe great men intirely agree with us in the eſſence of fire, on which its powers, qualities, and vigour depend.

Having then, in our Lectures on elaſticity, ſhewn that our elaſtic matter is the baſis of all lively powers and tremours in body, conformable to the opinions of Boyle and Newton, and in the preſent having ſhewn that expanſion or elaſticity is the eſſence of fire, and the ſource of its powers, qualities, and vigour: ſhall we ſay there are in nature two diſtinct principles, whoſe eſſence is the ſame, to wit, elaſticity or expanſion, the cauſes of all thoſe lively powers and qualities of body, and both already diſcovered in all the bodies we have examined, (inert matter alone excepted)? Shall we not rather conclude, that theſe two matters, as they are the ſame in eſſence, are alſo the ſame in ſubſtance, and conſequently, one and the ſame acting principle?

We have ſignified that elaſticity and expanſion are one and the ſame eſſence, and with juſtice; for expanſion cannot ſubſiſt without elaſticity, and both are exertions of the ſame ſubſtance, as it is differently excited: for, while our elaſtic matter, in its natural adheſive ſtate, continues blended and united with all parts of the body, it remains dormant therein, and only diſcovers itſelf by the elaſticity and other qualities, with which it endows the body, and which may be judged of by the variety of volatile and factitious airs thence extracted. But when the body is urged by a ſtroke, or friction, or heated by any other means, the elaſtic matter thus collected and agitated, exerts an expanſive force, which originally proceeded from the repulſive tremours of elaſticity; for the elaſticity of this matter, cauſes the impreſſion made on one part to communicate throughout the whole, and to produce a general reſtoration, which, when exerted on all ſides, is called *expanſion.* If the cauſe of excitation be continued, the elaſtic matter collected, agitated, aud vivified, at length acquires that expanſive bridled motion, which Bacon deſcribes ſtruggling in the particles of the body, to generate heat. This heat will again excite a greater degree of expanſion in the elaſtic matter, while its crouding and ſtruggling is ſtill continued by friction, until it breaks forth in actual flame, and obtains that ultimate degree of expanſion, which drives out its heat and light, ſo as to warm and illuminate the ſurrounding bodies. Expanſion therefore, is no other than a repulſive elaſticity, acting at a central part, from whence it propels in all directions; take away then elaſticity, and this repulſion is loſt, and conſequently expanſion ceaſes.

Again, to make this conception more eaſy, every individual part of this matter is ſimply elaſtic, while it quietly inheres in a particle of inert matter, and only gives to this particle a power of reſtoring itſelf, if compreſſed; but if that part of the elaſtic matter be excited by heat, then its ſimple elaſticity changes into expanſion, by getting a repulſive power through the agitation induced by heat; for a collected body of theſe individual parts, when agitated, will, by their co-action and repulſion, generate expanſion: however, the ultimate degree of expanſion is not attained until the body be kindled to flame.

Hence we ſee the cauſe and mode of exudations and perſpirations in animal and vegetable bodies; we ſee why heat excludes and propels their juices and odorific ſubſtances; why a diſagreeable ſmell ſurrounds an animal body in the ſtate of putrifaction, and extends to a diſtance. This laſt effect, is a plain indication of the expanſive motion and form the elaſtic matter acquires, when excited and enlarged by the heat and diſſolution of the parts, which attend putrifaction. In the dark we ſee a glow of light ſtand round the putrid body, which again proves that the elaſtic matter, when agitated and collected, aſſumes the form of light; if ſtill more crouded, ſo as to ſtruggle with greater violence, it begets flame and fire, as in moiſt hay, and heated vegetables: thus we ſee our elaſtic matter is the baſis of flame or fire, as well as of light, when its elaſticity is improved into expanſion.

Theſe proofs drawn from experience, at once confirm the theory above delivered, and the axioms on which it reſts; which axioms may be applied to our preſent purpoſe by this argument. Subſtances, we have ſhewn, are ever adequate to their eſſences, but the eſſences of the elaſtic matter and of fire have been proved the ſame; therefore their ſubſtances are alſo the ſame, and therefore the elaſtic matter is the baſis of fire, that is, fire is the elaſtic matter modified and vivified into the form of flame.

Thirdly, we have alſo remarked a ſoft mild flame excited by rubbing together a ſoft and hard body, which is called *electricity;* we have obſerved that a violent rubbing and daſhing of the waves occaſion light, accompanied with a ſmall degree of heat, in the ſame manner as the copious effuſions of the elaſtic matter, produce both in a putrid body. Light, in theſe two inſtances, has not an intenſity of flame, or power of burning ſufficient to kindle the moſt inflammable body, while electricity will kindle gunpowder or rectified ſpirits; and the flame excited in very hard bodies by friction or colliſion, will kindle not only combuſtibles, but even the firmeſt kind of fuel. Whence we ſee that the mode of operation is the ſame in all; that there is only a difference in the effects, correſponding with the contexture and firmneſs of the operating bodies: conſequently, ſimilar principles in theſe bodies, produce thoſe ſimilar effects; or, we ſhould rather ſay, the ſame principle produces ſimilar effects, when ſimilarly contextured in different bodies, and different effects, when differently contextured.

Hence we may eaſily infer, that if the principle, which thus indicates fire differently in the bodies, though the mode of operation be the ſame, were alike tied down and contextured in all, it would, from the ſameneſs of principle, operation, and contexture, produce the ſame intenſity of flame. And as the difference of intenſity may be explained by the difference of firmneſs and texture, we may pronounce the principle of fire to be the ſame in them all: for we know from the focal power of a burning-glaſs, that light is a diffuſed flame, and flame a compacted light. Since therefore, what we call the elaſtic and electric matters, produce, by the ſame mode of operation and excitation, effects ultimately coinciding, their principles muſt coincide, and be one and the ſame thing.

For, ſince experimenters in electricity aſſert, that every elaſtic body contains its electric matter, as we have proved that all ſuch bodies contain their elaſtic matter, and ſince the eſſence of both is the ſame, to wit, expanſion, will any one, who conſiders the ſimplicity of nature, ſay they are different principles? Principle conſiſts of ſubſtance and eſſence; ſubſtances too are as their eſſences, and eſſences are known by their propenſities; as therefore the eſſences are here the ſame, it follows, that the ſubſtances are the ſame: therefore the electric and elaſtic matter diſcovered in bodies are one and the ſame principle.

Thus we ſee that the elaſtic matter is identified with the electric matter, and exhibited therein: ſo that its being is ſenſible to every one that has either ſeen or felt the phænomena of electricity. The electric matter is tranſported and conducted from body to body, as we have ſeen the elaſtic paſs from body to body, and thereby ſuperinduce on one body the qualities of another. Again, like the elaſtic matters of different bodies, ſo the electric matters of different bodies blend, when in fuſion; for glaſs, wax, &c. though *electrics per ſe* when hard, become *non-electrics* when ſoftened by heat, or brought to a ſtate of fuſion; which is a further confirmation of our concluſion. We have already diſcovered in our elaſtic matter, the etherial medium of Newton, the elaſtic ſpecies of Sir Robert Boyle, and the elementary fire of Boerhaave, into the laſt of which forms it evidently changes, when collected and agitated by friction, colliſion, putrifaction, or torrifaction, as may appear from the recapitulation, or from an impartial review of theſe ſubjects where they are ſeparately treated. The truth of this theory will hereafter more fully appear, when experimenters in electricity and chymiſtry, and other eſſayers on the powers and operations of nature, ſhall follow the mode of reaſoning here practiſed, to wit, from *the ſimplicity of nature*, *the fitneſs of things*, and other axioms, founded on the power and wiſdom of the Creator.

Thus we have ſeen, that all the great philoſophers of the laſt and preſent age (who in moſt things, experimental phyſics particularly, have excelled their predeceſſors) agree with us in one univerſal expanſive principle, though under different names; this principle we have alſo traced through all the bodies of the earth, animal, vegetable, and foſſil, and even through the elements, fire, air, earth, and water; not by juggling inſtruments, contrived to favour particular hypotheſes, nor by forced experiments, which, like the torture of the inquiſition, ſeldom extort real or uſeful diſcoveries; but from the ſimple operations of nature, from the natural modes of theſe operations, and the effects thence ſpontaneouſly ariſing. In the next Lecture, we ſhall take into conſideration thoſe of its properties which have not been as yet ſufficiently examined, in order that having fully inveſtitaged the ſubſtance, eſſence, and primary qualities of this univerſal *principle*, it may be accurately defined. Its definition being formed, and its nature determined, it will the more eaſily be diſtinguiſhed from any other natural *principle*, which may hereafter emerge in the courſe of inveſtigation, and we ſhall be the better enabled to explain its effects, and employ its agency for our various uſes and neceſſities, which ſhould always be a principal object in the cultivation of ſcience.

LECTURE VI.

The Texture, Compoſition, and Eſſence of the Elaſtic Matter examined and defined.

SECTION I.

Texture of the Elaſtic Matter examined.

HAVING now fully aſcertained the exiſtence of the elaſtic ſubſtance, by purſuing it through the various forms it aſſumes, whether from the nature and context of the body, in which it inheres, or from the different operations, by which it is excited: the true method of philoſophizing requires, that we ſhould at preſent collect from all our reſearches, the diſtinctive nature of this ſubſtance, and its peculiar eſſence, to form its real and accurate definition. This however, upon examination, we find ourſelves ſtill unqualified for; our inveſtigations have not as yet diſcovered, nor have we hitherto taken into conſideration the texture or conſiſtency of this ſubſtance, that is to ſay, whether it be one *continuum* of matter, wherever it exiſts, or be compoſed of particles interſperſed with pores, as groſſer matters are ſuppoſed to be. A doubt of this nature is ſo contrary to general prejudices, that the enquiry to numbers may appear ſuperfluous and groundleſs. But in true philoſophy, no point is to be decided without proof and examination; and beſides, it will ſoon appear, that the conſideration of this ſubſtance ſhould naturally create a ſuſpicion of its being continuous.

Again, we have not as yet ſufficient information relative to its eſſence; for, although all the operations of this ſubſtance are analogous to expanſion, which the learned Boerhaave juſtly ſtiles the eſſence of fire, and all its ſenſible qualities ſeem to originate in that power; yet the nature of tremour, which is its moſt conſtant and univerſal effect, requires ſome active power different from expanſion; for an elaſtic wave, at the ſame time that it expands and widely diffuſes itſelf through the agitated medium, carries with it ſome curb or reſtrictive power, which, with inſtantaneous pulſes counteracts the diffuſive principle, and excites a tremulous vibration.

Beſides, we have often, in the courſe of theſe Lectures, diſcovered the elaſtic matter in an adheſive, connected form, and apparently of greater ſpiſſitude in ſome bodies, (in metals, for inſtance,) than in others: now as adheſion is contrary to expanſion, ſince we ſee this ſubſtance is adheſive, *mere expanſion* cannot be its eſſence. We ſhall therefore continue our reſearches, confident, that the ſolution of elaſticity and of many other properties of matter, and operations of nature, depend on a true and accurate knowledge of the ſubſtance and eſſence of the elaſtic matter.

But firſt, as the continuity of ſubſtance is a property not conſidered in our modern phyſics, the term may not be readily underſtood: we ſhall therefore explain it. By continuity of ſubſtance, then, I mean that this material ſubſtance is not compoſed of atoms or particles that were originally diſtinct and ſeparated from each other; but that it is one continued maſs, without pores or interſtices, as we conceive any one ſingle atom or particle to be, according to our modern phyſics, in which particles are ſaid to be impenetrable, poreleſs, and even indiviſible. We however allow our continuous matter, though poreleſs, to be penetrable, and even indefinitely diviſible, that is, diviſible farther than the mind can carry its conceptions of diviſion; which laſt property would be impoſſible, were the component particles impenetrable and indiviſible.

Our conception of continuity may be illuſtrated by the idea of a mathematical line. This line is not compoſed of diſtinct mathematical points, but generated by the motion of a ſingle point; and in this conſiſts its continuity as far as it reaches. Whence a mathematical line may be extended, ſhortened, or curved, without the idea of its cracking or breaking, which could not be ſo properly ſaid, were it compoſed of points or parts joined together. If lines were thus compoſed of points, no two of them could be incommenſurable, as the ſide of a ſquare and its diagonal are found to be; for, if they were, a point would be the common meaſure of both.

But as mathematics are a ſcience founded on idea, which takes its origin in the mind, not in a knowledge of matter, and is only applicable in phyſics, in as much as it ſerves for the menſuration of body, and for the calculation of effects ariſing from powers already diſcovered; or like logic, to form the mind to preciſion, and render it capable of a train of ratiocination; therefore an illuſtration taken from this ſcience may ſeem improper, as founded in idea. To obviate any difficulty on this head, we ſhall explain our idea of continuity from the received notion of a particle of matter, which, we preſume, all who have read the modern phyſics are ſufficiently acquainted with.

Sir Iſaac Newton, towards the concluſion of his laſt query, ſays, "It is probable that "God in the beginning made matter in ſolid, "maſſy, hard, impenetrable particles, of ſuch "ſizes and figures, and with ſuch other properties, and in ſuch proportion to ſpace, as "moſt conduced to the end for which He "formed them; and that theſe particles, being ſolids, are incomparably harder than "any porous body compounded of them." Let this notion be broached for what end it may, it is only advanced as a probability:

but it is a certainty, that the Creator of ſubſtances was not, in the creation of matter, confined to any particular form, texture, or conſiſtency whatſoever; neither to hard nor ſoft, to indiviſible particles, nor conſiderable maſſes, nor to any particular ſize or figure: we are convinced, that He made every material ſubſtance, eſſence, power or propenſity that was neceſſary or uſeful for the nature He had in idea at the time of the creation; that He made all beings perfect, and endowed them with ſufficient efficacy to conſerve that perfection, to perform their functions, and to anſwer the end for which they were deſigned, ſo that they now continue what they originally were; and ſuch as we find them, ſuch we ſhall conceive them to have been created: allowance indeed muſt be made for the changeability of powers and qualities, with their concomitants, according to the changes we experience in nature, which her principles were originally adapted to produce. This rule being laid down, we ſhall take one of theſe particles into conſideration, and we ſhall find Sir Iſaac Newton himſelf as much involved in the continuity of matter with regard to his particles, as we are with regard to our elaſtic matter.

"Solid, maſſy, impenetrable particles" he ſays, "incomparably harder than any porous "body compoſed of them." Conſequently, according to him, each individual particle is void of pores, that is, continuous in texture and ſubſtance. "Of ſuch ſizes," &c. he ſays, therefore he admits it may be of any ſize, proportioned to ſpace, and conſonant to the end for which it was made. Here we have a poreleſs maſſy particle of any ſize, may it not therefore be as big as a foot-ball, nay as large as the earth or its atmoſphere, if you pleaſe? Have we not thus the idea of a large maſs of poreleſs matter, continuous in texture and ſubſtance, and free from every notion of interſticial vacuities, which is the very thing I mean by a continuity of ſubſtance in the elaſtic matter?

But to come to the application of this conception, let us conſider how far this property is realized in the flame, to which gunpowder is reduced in the chamber of a mine, or piece of ordnance, the inſtant previous to exploſion. Conceive the intenſity, the expanſive vigour, and the irreſiſtible force of the fluid thus confined, and retaining this idea, let us examine its texture and conſiſtency. But, preparatively to this examination, let us firſt conſider the flame of a candle, and think how poroſity can be imputed to that thin yielding flame, compreſſed on all ſides by the whole weight of the atmoſphere: if it be compoſed of pores and particles, there muſt be *ſomething* in thoſe pores or interſtices to keep the particles aſunder, in a fluid of ſuch tenuity, and ſo ſtrongly compreſſed on all ſides. Again, that *ſomething* muſt have reſiſtance, and that which gives reſiſtance is matter; conſequently, the ſuppoſed pores are full of matter; and if other interſtices are ſuppoſed to ſubſiſt between theſe, they alſo muſt contain their reſiſtive matters; ſo that every conceivable pore in this ſubtile fluid, muſt contain matter equally denſe to reſiſt the preſſure of the atmoſphere, which deſtroys the idea of interſticial vacuities. Therefore all parts of this flame are void of pores, or it is a *continuum* of ſubſtance. And this concluſion from reaſon, is confirmed by ſenſe; for who will deſcry or exhibit a pore therein, even with a microſcope? And where can light be ſo convenient to ſee them? Now if none are diſcoverable in, or imputable to the flame of a candle, which is as far inferior to the forementioned flame in ſpiſſitude, as it is in force, can it be ſaid that a flame, capable of ſplitting a rock, has pores, or interſticial vacuities? No, ſuch a conſiſtency would neceſſarily render its effect feeble, and be incapable of that expanſive force, which requires the ſuſtained effort of a continuous ſubſtance.

Should any philoſophy admit in a thing a property inconſiſtent with its nature? Should, at leaſt, a philoſophy grounded on experiment, admit a property repugnant to reaſon, unleſs its ſenſibility rendered its exiſtence in the ſubject undeniable? Now, in the flame under conſideration, vacuities, or unſuſtaining parts would deſtroy its repulſive power, and diſable it to expand with ſuch prodigious force. They would even deſtroy in it the property of fluidity; becauſe ſuch vacuities, in order to be preſerved in any ſubſtance, ſhould be bounded with firm particles, or partitions ſurrounding and framing in the pores; which would impreſs the notion of a cinder or pumice ſtone, rather than that of a liquid flame; and laſtly, no ſenſe can deſcry, or experiment diſcover them: this flame muſt therefore be continuous in ſubſtance, and void of pores.

We have ſeen, by the equal ſpecific gravity of the maſs, when cooled, that all kinds of metals, when fuſed together, are equally and intimately blended together. Their moſt intimate particles, pervaded by the piercing ſubtility of fire, diffuſe, expand, and mutually receive each other, ſo as to form an uniform and equal mixture of all. This is evidently diſcovered in the reſulting maſs; for, if the particles were not thus opened and diſſolved, but remained in their original form, perfectly whole and impenetrable; would not the gold ones, on account of their greateſt weight, deſcend all to the bottom of the fluid maſs, and, when cold, be found in one ſtratum under the other metals, which ſhould alſo form orderly ſtrata over each other, according as they are of leſs ſpecific gravity? Since then the cold maſs is not thus found compoſed of ſtrata of different metals; ſince it affords no diſtinction of metals, qualities, or ſpecific gravities, all the particles of the different metals muſt have been opened, blended, and equally diffuſed together by fire; which may again be proved by the tranſparency of well made and well poliſhed glaſs.

Glaſs is made of ſand, or pounded flint, and a fixt alkaline ſalt; if any bodies be compoſed of impenetrable hard particles, theſe certainly are; and if the particles of theſe bodies be indiſſolvible, they muſt reſiſt fire, and conſequently reſiſt and intercept light; and, by thus intercepting it, ſhould rather occaſion opacity than tranſparency. If then any glaſs be found that will tranſmit light through every part and point of its ſubſtance, and equally in every part, to the experimental ſatisfaction of every beholder, ſhall we not inſiſt, notwithſtanding contrary hypotheſes, and the notions of any philoſopher, however great his name may be, that there is not a point or part of that glaſs which is not pervaded by light? If ſo, then, each particle muſt have been pervaded and diſſolved by fire, and what is ſaid of one particle, may be ſaid of all: where therefore is the impenetrability of particles?

Metals, wood, vegetables, and moſt kinds of opake bodies will vitrify, when urged by fire; therefore they are ultimately compoſed of the ſame kind of particles with glaſs; but, as that ſubſtance cuts them, and ſeparates their particles, which effect they cannot produce upon glaſs, it follows, that the particles of glaſs are more cloſely united and contextured together, than are the particles of the opake bodies mentioned. Now if pores, not particles, were the paſſage for light, glaſs, being the leaſt porous of all theſe bodies, ſhould alſo be the moſt opake; but experience proves the contrary, to wit, that glaſs is tranſparent; therefore its ſolid particles have been pervaded by light, and, conſequently, they have been intimately penetrated by fire. Experiment proves the ſame converſely, for pound glaſs, and thereby give it pores, and it becomes opake; and a crack in a pane glaſs, will cauſe a ſhade in the tranſmitted light. Again, why ſhould pores be attributed to any body from prejudice alone, without proof or experiment? Now the beſt microſcope, the fineſt ſteel point, and moſt ſearching chymical ſpirits, are vainly employed to diſcover pores in well poliſhed glaſs.

Conſequently, metals, flint, foſſils, and vegetables, which are changeable into tranſparent glaſs, cannot be compoſed of impenetrable particles; and if not, neither can unctuous and inflammable matters, as ſulphurs, oils, ſpirits, &c. which are changeable to flame, which pervades glaſs, be compoſed of ſuch particles; much leſs can ſuch particles be aſcribed to the flame of a candle, or of gunpowder; and without the impenetrability of particles, there are no grounds for the ſuppoſed univerſality of pores, or vacuities in all kinds of matter. This prejudice then, being once removed, we may be induced to liſten to the dictates of reaſon, and the teſtimony of our ſenſes, both which atteſt that the ſubſtance of flame is a *continuum*: now if the elaſtic matter has a continuity of ſubſtance in its moſt exalted and expanſive ſtate, it muſt be proportionably more continuous in its denſer ſtate, if degrees of continuity be admiſſible.

Theſe reaſons are ſufficient to prove, that the elaſtic matter in every ſtate, whether hard, ſoft, or fluid, is continuous in texture and ſubſtance. Moreover, the lively ſounding, and uniformly continuous tremours of hard bodies, ſhew the continuity of this matter in them; for, were they made up of diſtinct particles, without any continuous pervading ſubſtance, their tremours would be diſcontinuous and broken, like thoſe of a cracked bell. The ſame may be ſaid of air and water.

In order however to be more fully ſatisfied about the reality of this property, which ſeems ſo conſpicuous in glaſs, and to elucidate the other object which ſtill remains for enquiry, to wit, the real eſſence of the elaſtic matter, we ſhall, in the following ſection, examine, in a radical manner, the ingredients of glaſs, which is ſtrongly impregnated with the elaſtic matter, which exhibits the moſt ſtriking properties of that ſubſtance, and is therefore a proper ſubject to illuſtrate its nature.

SECTION II.

The Coercive Principle inveſtigated.

THE ingredients and formation of glaſs we ſhall take from Boerhaave, who is generally very copious and judicious on chymical ſubjects. "If" ſays he (vol. 1, p. 458) "one hundred parts of pure ſand, or calcined flint are reduced to a fine powder like "flour, and then intimately mixed with "one hundred and fifteen parts of a pure "fixed alkaline ſalt, powdered likewiſe very "fine, and this mixture is then expoſed to a "moderate fire in a glaſs-houſe arch for an "hour, and kept conſtantly ſtirring; and afterwards, keeping it continually ſtirring, "to a ſtronger fire for five hours or more; "you will, by this means, prepare a matter

“ which will have the diſpoſitions neceſſary “ for making the choiceſt glaſs: but if this, “ however, is then put into a good dry “ caſk, and ſet in a dry warm place for four “ or more months, the combination of the “ alkali and the flints will be ſtill further “ perfected. This matter, ſo prepared, being put in glaſs-houſe pots, and expoſed to “ the intenſe heat of the furnace, will melt “ into a thick *tenacious pinguous* kind of liquid, and, whilſt it is boiling there, it will “ caſt up a ſcum to the ſurface, which, continually increaſing more and more, riſes “ often to a fourth part of the whole maſs. “ When the ſcum now is carefully removed, “ till there appears no more of it, and the “ pure deſpumated matter has been kept two “ or three days in fuſion, what then remains “ in the pot the workmen call the *metal*, “ which, when it comes to harden in the “ cold, produces the fineſt glaſs.”

“ If this was not evident from common “ experience, what mortal living” continues he “ could ever have imagined that a ſolvent “ alcali, ſpontaneouſly diſſolving in the air, “ could, when it was rendered vaſtly active “ by the intenſeneſs of fire, be converted,

" with the ſolvend, into a metalline maſs, " perhaps, ſetting aſide its want of malleability; this property therefore of alkali muſt " be inſerted of the power of alkaline menſtruums. For here, when the alkali, by " the action of fire, is made to flow like water, it hence becomes capable of ſolving the " powder of flints. In the ſame manner, and " by the ſame means, it becomes ſo altered " itſelf, that it retains nothing of its former " diſpoſition; but entirely acquires a new " one. Hence you ſee that menſtruums, " and thoſe very powerful ones too, may be " joined in an indiſſoluble union with thoſe " bodies, which they have moſt intimately " diſſolved."

" In this operation," he ſays, " it is very " remarkable, that this alkaline ſalt, ſhould, " in the very act of ſolution, immediately " put off all its alkaline nature, as ſoon as " ever it is converted into glaſs; for, of all " the proper characteriſtics of an alkali, there " is not ſo much as one left. It has loſt its " taſte; it does not cauſe an efferveſcence " with any acid; it makes no alteration in " colours; it becomes exceedingly ſoft, and " perfectly free from any cauſtic acrimony;

“ nay, it is much more fixed in the fire, when “ it is turned into glaſs, than it was before, “ when it exiſted in the form of an alkaline “ ſalt. But how very difficult it is now to “ put it into fuſion, as it requires ſo ſtrong a “ fire for ſo long a time applied to it, to “ make it melt! And, which is ſtill more “ ſurpriſing, as ſoon as it begins to flow, and “ is converted into glaſs, it becomes *a tenacious maſs, cohering together like pitch, and ſo* “ *ductile and pliable, that you may form it into* “ *whatever ſhapes you pleaſe; nay, if you thruſt* “ *an iron into it, it will adhere to it, ſo as to come* “ *out of the melting pot with it, and be retained* “ *upon it.*”

For our preſent purpoſe, the nature of this alkali, which is ſo principal an ingredient in the compoſition and formation of glaſs, muſt be accurately inquired into. It is therefore uſeful to remark here, that thoſe characteriſtics of alkaline ſalt, which have been thus loſt in its transformation into glaſs, do not conſtitute the intimate nature or eſſence of the ſalt; for we have proved, in our firſt Lecture, that the ſubſtance and eſſence of every elementary principle are co-eval, co-exiſtent, and inſeparable: conſequently, neither taſte nor colour, neither the burning nor effervеſſive power, is the eſſence of the alkaline principle: theſe properties are therefore only acquired by it, through its intercourſe with other matters, and the modifications it thence receives. The only property which ſeems moſt conſtant and inſeparable from alkali, is tenacity and fixedneſs. Glaſs, when melted, is a *tenacious maſs, cohering together like pitch*; and, when cold, is an hard coheſive body. We find by experience, that fiſh and fleſh are rendered cloſe and firm by ſalt; and ſalt itſelf, in its perfect ſtate, when free from moiſture, is of an hard conſiſtency; thus we ſee *tenaciouſneſs*, or a compacting quality attend it in every ſtate; may we not therefore flatter ourſelves, with having in view ſome indications of its real eſſence?

If it be objected, that the coheſion of ſalt is weakened and even deſtroyed by moiſture, we may make the ſame obſervation on the ſubſtance of light or fire, whoſe expanſion, though undoubtedly its eſſence, is reduced and apparently deſtroyed by humidity, as is evident from the extinction of fire by water, and from the abatement of exploſive force, which gunpowder ſuffers from moiſture. However, to aſcertain the truth of this conjecture, and obtain a more perfect knowledge of its nature, we ſhall trace alkaline ſalt to its origin.

Boerhaave tells us, (page 440, vol. 1) that "*kali* in eaſtern countries, ſignifies a certain "herb abounding in ſalt, that grows near the "ſea, on the banks of the Nile, and in other "parts of the Eaſt. This plant, when burnt in "an open fire, produces aſhes that are remarkable for their ſalt and acid taſte; theſe aſhes "boiled in water, yield a ſtrong liquid ſalt "lixivium. If this lixivium is evaporated to "a dryneſs in an iron kettle, there is left behind a white ſolid maſs, of a moſt acrid "cauſtic taſte, and perfectly ſoluble in water. "From this ſalt, and the calx of all ſtones that "ſtrike fire with ſteel, may be prepared a frit "for the making of glaſs. For ſoaps they uſe "the ſame, made ſharper with quick lime, "and any oily ſubſtance whatever."

The ſame kind of ſalt is to be gained from kelp, which is made of ſea-weed; and here in Ireland from ferns, thiſtles, and nettles, from the ſmall branches of oak and aſh, and from moſt kinds of young trees and ſhrubs, which, being burned in due ſeaſon, produce aſhes very generally uſed for purging bay yarn, for whitening linen, and alſo for making ſoap. According to Boerhaave, the potaſhes that are brought to us from Ruſſia and Poland, are of the beſt kind of alkacious ſalts, and are prepared from the wood of green fir, pine, oak, and the like. An alkali is procured from the lees of wine, *from nitre by means of fire*, from nitre and tartar, from antimony; but by no means, as this author aſſerts, from ſea ſalt.

We might with ſome probability infer, from the known properties of alkali, for inſtance, from its cauſtic quality, from the volatile it contains, its generation by fire, and the quantity of water it abſorbs, that it involves and retains in its compoſition the ſubſtance of fire or light. For all theſe effects muſt proceed from that principle, and argue its exiſtence in the alkali. However, we ſhall be better enabled to verify this and other remarks on that ſalt, by inquiring into the origin of nitre, which, as well as vegetables, we find to be a principal ſource of alkali.

“ Nitre * is a white and nearly tranſparent “ ſalt; it grows liquid by a gentle heat, in a “ great fire; it partly perſpires through the “ veſſels that contain it, and partly reſolves “ into ſmoke; but any inflammable body being added to it, it burns with a very great “ noiſe, and, with the matter added, changes “ in part into an alkali.” “ Nitre,” ſays the ſame author, (page 177) “ is engendered on “ the ſurface of the earth; it is never gotten “ out of mines, for, if you dig into the earth “ above one foot deep, you hardly find any “ more matrix impregnated with nitre; nor “ is it even found at ſo great a depth, unleſs “ it has been by waters waſhed off from its “ matrix.—The chief matrices of nitre are calcarious, clayey, loomy earths, and a kind “ of moiſt earth, which has all its origin from “ vegetable and animal bodies deſtroyed by “ the viciſſitudes of the air. If therefore you “ join to them aſhes of burnt vegetables, “ eſpecially of thoſe out of which a great “ deal of fixed alkaline ſalt is fetched by fire; “ if the ſaid aſhes are not quite deprived of “ their ſalt by boiling, and if the fat oily

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[*] See Cramer on the Aſſaying of Metals.

" rottening, or already rotten parts of the " animal or vegetable bodies are added, " then a perfect generation of nitre is per- " formed in the ſaid matrix; for there is " never any nitre produced in an earth " quite deſtitute of all phlogiſton.—Nor is it " very important where this matrix of nitre " is placed; for there never was yet any " place found unfit for the generation of " nitre, provided the above-ſaid bodies con- " cur to it. However, it is neceſſary that " the place be in the open air, and temperate " as to moiſture and dryneſs; for an exceſ- " ſive humidity waſhes off the nitre already " conceived: and when a diluting moiſture " is altogether deficient, the ſaline matters " hardly act one upon another. In the mean " time, it is certain that heat and cold are " neither much uſeful nor noxious, unleſs " both be very exceſſive." Whence he concludes, " it is moſt probable that *the air is* " *either the inſtrument, or the material cauſe, or* " *perhaps both together, of the generation of* " *nitre, or at leaſt carries it in its boſom.*"

Here we muſt obſerve, that the generation and perfection of nitre and vegetables, depend on the ſame cauſes, to wit, a good ſoil, the open air, temperate weather, &c. with this difference, that a vegetable grows from a parent ſeed or root planted in this matrix; whereas the nitre gets birth and grows in the matrix ſpontaneouſly, without any ſuch ſeminality, at leaſt that we know of. Whence it appears, firſt, That vegetables, like nitre, would come to a ſameneſs all over the earth, without diſtinction of form and qualities, were it not for the Divine and efficacious Word, which firſt gave them their diſtinctive properties, and afterwards ordained that each ſpecies ſhould generate according to its kind, whereby the diſtinction of ſpecies is ſtill preſerved in the vegetable kingdom, as well as in the animal. Secondly, That the ſaline juices of vegetables are nitrous, but more refined, being better elaborated in the vegetable, than on the ſurface of the earth in the nitrous matrix; for, ſince the ſoil or matrix of vegetables and nitre is the ſame, and their other accretions (an inconſiderable ſeed alone excepted) are alſo the ſame; ſince, on the application of fire, both are reduced to the ſame alkaline ſalt, their original principles muſt be the ſame, or they muſt be compoſed of the ſame original matters.

Now we have ſeen that vegetables contain, along with a virgin earth, our elaſtic matter, and alſo of neceſſity another ſpecies of matter blended with both, to unite and compact them, and perhaps to produce their gravity. Whether any chymiſts have aſcertained theſe diſtinct principles in genuine nitre, I cannot ſay, but they ſeem to be inſinuated by Boerhaave in theſe diſtinctions, to wit, the volatile part, the pure earth, and the bitter ſalt of alkali. We have underſtood above from his obſervations, that neither the bitter nor ſalt taſte, the colour, nor the other amiſſible qualities, are the eſſence of that principle; the eſſence then of this bitter ſalt ſeems to be analogous to the cauſe of coheſion, ſo that in it probably conſiſts the adheſive power which binds thoſe matters ſo firmly together, and renders them an hard compound body: for the inert matter or pure earth, being perfectly neutral and paſſive to every agent, cannot be the cauſe of coheſion in itſelf; nor in the other matter it emboſoms; and light, being of an expanſive nature, not only is unfit for binding down another principle, but cannot itſelf be bound down, unleſs by a powerful agent of different propenſity, that is, of a convergent nature, which is the very eſſence we have, throughout our rules and philoſophical inveſtigations, aſcribed to the gravitating matter.

From theſe reaſons, and the apparent qualities of the bitter ſalt which ſeem indicative of the predominant power of alkali, we may infer, as a probable conjecture, that the adheſive matter, and the element of ſalt, have one and the ſame principle: for all chymiſts allow, with the Hermetic philoſophers, that ſalt is a binding principle, or the *vinculum* whereby the other elementary matters are united together. Metals are compoſed of ſalt, ſulphur, mercury, and earth; if then, in this compound, the earth gives firmneſs to the volatile ſubſtances, may not ſalt be the cauſe of their coheſion, and perhaps occaſion their weight? This will agree with the concluſion of Mr. Geoffry, who collects from experiments and extenſive obſervations, that the ſubſtances, of which metals are compoſed, do not differ eſſentially from thoſe which compoſe vegetables.

Although we cannot, without a perfect knowledge of the cauſe of coheſion, and a better acquaintance with the elementary origin of nitre, poſitively ſay they have one and the ſame principle, it is uſeful and even neceſſary in analyzing firſt principles, which, from the ſimplicity of nature, cannot be numerous, to approximate to the emerging principle by analogy, whenever the ſimilarity of effects, modes of operation, and other concurring circumſtances will permit; particularly when the principles or ſpecies of matter are ſo obſcure, as are thoſe under conſideration, to wit, the cauſe of gravity, and the ſource of nitre. It is therefore highly expedient in philoſophizing, to make probable conjectures wherever an opportunity occurs, and to keep them in view, in order to direct and illuſtrate future reſearches; we ſhall therefore continue our obſervations in hopes of confirming and improving the indications we have gained.

" There is alſo an acid ſalt," ſays Doctor Cramer, treating of this ſubject " called a " *vagum foſſile*, found in vitriol, ſulphur, al- " lom, nay almoſt every where. It is ſel- " dom pure, if ever; but adheres either to " metals, (and chiefly to copper and iron) or " to calcarious earths; more commonly to "thoſe that turn into glaſs, nay to the very "flints, or is mixed with inflammable foſſils: "but what diſtinguiſhes it from all others, is "its being more *ponderous* and more *fixed* "than all the other acids that are known, "which it derives out of its matrices. Mixed "with pure water, it grows very warm; it "mixes with common ſulphur accompanied "with fat matters of any kind. To this "claſs might be referred the acid of com"mon ſalt and nitre."

Phyſically ſpeaking, it is impoſſible to have an effect without a cauſe, or any offspring without a parent: is not then this *vagum foſſile* the ſource of vegetable and animal ſalts, nay of all ſalts whatever? It is found every where, and is of a crude nature in its original ſtate; but, like the elaſtic matter, may it not be elaborated and aſſimilated to a conformity with the nature of the body into whoſe compoſition it enters, whether the body be vegetable, animal, or foſſil, as we have obſerved of elementary matters in our fourth Lecture? This acid adheres more to copper and iron than to any other metals, and theſe metals are more affected and corroded by our air, than any others; for, when expoſed to it, it is almoſt impoſſible to keep them from ruſting, which is the effect of a ſalt or acid. Our air is therefore impregnated with an acid, and this ſhould naturally be the ſame with that *vagum foſſile* which is found every where.

Nitre, which is found on the ſurface of the earth, and cannot be generated, unleſs where the air has free acceſs, muſt, according to Cramer's remark, derive its origin from the atmoſphere; for, if the ripeneſs and improvement which fruits receive from the ſunſhine are proofs that they imbibe the light, and are to it indebted for their fineſt qualities; for a like reaſon we muſt conclude, that the air is the chief ſource and generant of nitre: therefore there is in air ſome parent principle of the nitrous kind, which can be no other than the *vagum acid*, which corrodes metals, and whoſe influence generates the pelicles or ſcoria on fuſed lead, which pelicles contain ſo much of the alkaline nature as to vitrify other bodies: and doubtleſs it is the ſame *vagum acid* which ſours milk, wine, and other liquors when expoſed to the air, and which imparts to ſweet vegetable juices, ſuch as worts, muſt, &c. the acidulous taſte they acquire by fermentation, whereby they are rendered agreeable and inebriating liquors; for the quantity they incorporate of that coercive matter renders them tenacious, and concentrates in the fermenting fluid a proportional quantity of light and fire, which, when enlarged and excited to action by the heat of the body, unites with the elaſtic matter of the nerves, and invigorates their action; but, if taken too copiouſly, produces the tremours and diſorderly ſymptoms of intoxication; all which is corroborated by Boerhaave's obſervation (page 283) "that "fermentation is the productive cauſe of "wine," *i. e.* that this liquor can never be produced unleſs the air has a free acceſs to it.

This nitrous principle, while in its native form in the air, is in a crude ſtate, but from the rich ſubſtance that compoſes the matrix, along with the influence of the ſunſhine, it is meliorated, it gains inflammability and other qualities, and is transformed from a crude acid into what we call *nitre*. In like manner, that part of this crude acid, which enters into the compoſition of other bodies, will be ſtill differently elaborated, and as we have obſerved of other accretions, will acquire the qualities of the body in which it becomes a part; and when that body is diſſolved, will be again extracted from it in the form of a particular ſalt. The heavy nature of the ſame principle might make it deſcend into the ſea, and even into the earth, whereby it might be the ſource of ſalt jem and ſea-ſalt; and thus, from one univerſal principle, may proceed all the varieties of ſalts, which are found throughout all the bodies in nature; and likewiſe from the different quantities of it in different kinds of bodies, may proceed their different ſpecific gravities.

All native ſalts, according to Homberg, are reduced to three kinds, ſaltpetre, ſea-ſalt, and vitriol, each of which has its ſeveral ſpecies; of the combination of theſe with different oily matters, are all the other ſalts produced. By the analyſis made by this author, they appear to be compoſed of an aqueous, an earthy, a ſulphureous, and an acid part; but the acid part he holds to be the pure ſalt, the chymical principle, and the baſis of all ſalts.

From the affinity, then, that ſubſiſts between the various ſpecies of ſalts and acids, from their mutual convertibility into each other, which is doubtleſs capable of being extended much farther than adepts have hitherto carried it, as may appear from the reſolution of all ſalts into the ſame elementary parts, and from the ſimplicity of nature, which varies and multiplies effects without multiplying principles, we have the ſtrongeſt reaſon to conclude, that theſe ſeveral ſpecies all originate from one grand *principle*, which is variouſly modified according to the nature and qualities of the other bodies, of which it becomes a concrete in the courſe and operations of nature.

This inference is ſtrongly confirmed by analogy; for we have ſeen, in the fourth Lecture, that the ſubſtance of light enters into the compoſition of all bodies, that in them it is the baſis of all their lively powers and qualities, partaking of the diſtinctive nature and ſenſible qualities of each, wherein it is a concrete, but in all retaining its own expanſive eſſence; ſhould we not therefore, from the ſimplicity and uniformity of nature conclude, that the principle of ſalt, which is alſo univerſal, enters into the compoſition of all bodies, communicating to them its guſt and qualities, but, at the ſame time, partaking of their ſenſible qualities and characteriſtical properties, in a manner peculiar to their reſpective natures, ſo as almoſt to produce a diſtinct kind of ſalt, for each diſtinct ſpecies of body, in which it is incorporated, retaining however its own eſſence, and diſplaying it by the firmneſs it gives them.

To puſh this analogy one ſtep farther, as light has a peculiar ſource and fountain, whence it is diffuſed univerſally, and enters into the compoſition of all bodies; ſo ſalt, which is generally diffuſed, at leaſt around the earth, being found in all bodies, ſhould have ſome one ſource, where it is ſtored, or where it originates. If ſo, the atmoſphere ſeems to be the only fund commodiouſly ſituated, and qualified to contain and diffuſe it: and it is the more probable, that the atmoſphere is its native place of reſidence, from what has been ſaid of the generation of nitre, and of the *vagum foſſile*, the latter of which ſeems to be the ſource of the former, and of every other ſpecies of ſalt, in vegetable and animal bodies. However, this *vagum foſſile* may not be itſelf the native principle, but generated therefrom, and formed by the luminous and earthy matter it meets with, and unites to in the atmoſphere, wherein it is elaborated into the form of a *vagum foſſile*; and this, being a part in the compoſition of that air which animals and vegetables imbibe, is in them ſtill farther elaborated and aſſimilated into the kind of ſalt which they reſpectively contain. From the atmoſphere then the principle of ſalt may conveniently enter into the compoſition of all bodies, producing, by its coercive eſſence, their coheſive firmneſs, and binding down their fires in the boſom of their inert matter; an effect, which, conſidering the expanſive nature of fire, and the total inertneſs of virgin earth, could not be produced without this coercive ſubſtance.

So univerſal is ſalt in all terreſtrial bodies, that when they are diſſolved by fire, and thereby deprived of every thing adventitious, ſalt is one of the three elementary parts that remain: and ſince light, earth, and ſalt, are the three parts into which all bodies are reſolved by torrifaction, ſhould we not conclude, that theſe are the accretions that compoſe bodies, and are their elementary ſubſtances? Now, as an elementary body, ſalt ſhould be univerſally diffuſed; as an accretion to vegetables and animals, it ſhould be conveniently placed for their abſorption; both which conſiderations confirm its reſidence in the air. Again, experiments prove that ſalt is found in vegetable, animal, and foſſil bodies, the moſt remote from the ſea, ſalt-pits, and fountains; but what is ſtill more remarkable, the young of all animals, before they take any other nutriment but the milk of their dams, are found to have a ſalt in their animal fluids; and even the perſpiration, blood, and urine of infants born of the moſt delicate parents, and ſuckled by a nurſe, whoſe diet is the moſt innocent and pure, will, notwithſtanding every precaution, diſplay the ſaline principle by their urinous acid taſte. Now ſince theſe infants taſte no food impregnated with ſalt, whence comes it that their animal fluids are ſo ſtrongly tinctured with that ſubſtance? Certainly it muſt be from the air they inſpire that they derive, not only the ſalts and acids, with which they are impregnated, but alſo the ſtrength, firmneſs, and elaſticity of their bones and muſcles. Moreover, there have been perſons of ſuch habit of body, that they have produced and paſſed more urine, not only for days, but for weeks ſucceſſively, than they have taken in of ſolids and fluids together by eating and drinking; whence alſo this extraordinary production of an acid ſubſtance, except it came from the air inſpired?

From the ſalts of the atmoſphere alſo, are acquired the guſts and flavour of all that we eat and drink, and by their influence is produced that heavy mephitic air which ſeems to exhale from fermenting liquors. But, though it were to be doubted, whether the atmoſphere be the fountain of this ſaline principle or not, at leaſt, from univerſal obſervations, we muſt neceſſarily conclude, that there exiſts in nature ſome material agent, of a binding concentrating nature; for, as we have already obſerved, light being of an expanſive propenſity, and inert matter having no propenſity at all, the former could never gain that firmneſs of texture and compactneſs which is implied by the idea we have of elaſtic matter, and which it exhibits, while it remains in that form, in the compoſition of a body: much leſs could that expanſive ſubſtance be chained down in the boſom of inert matter, without ſuch a binding coercive principle. Seeing therefore that a concentrating matter is neceſſary, as well for the elaſtic firmneſs of the expanſive matter, as for the coheſive firmneſs of inert matter, we cannot heſitate to admit its exiſtence in nature. And if we cannot doubt the exiſtence of ſuch a ſubſtance, why not conclude, from the univerſality and known properties of ſalt, that the ſubſtance we ſpeak of is realized therein? This concluſion promiſes a beautiful correſpondence in the agents of nature; for as Cramer declares the *vagum foſſile* to be the heavieſt of ſalts, as it is the moſt genuine, that principle may therefore be the cauſe of coheſion, gravity, and guſts, while its oppoſite, to wit, light, is the ſource of expanſion, levity, and odours.

SECTION III.

The Coercive Principle in the Compoſition of the Elaſtic Matter.

ALTHOUGH we have no ſtandard to aſcertain the exact portion of luminous matter in bodies, yet we have the ſtrongeſt proofs that they contain a prodigious quantity of it; of this number is the inſtance of the burnt vegetables, where we have remarked that of an whole tun of them, there remained not half an hundred weight in the form of ſalt and aſhes, having been for the moſt part changed into vapour and light, whereof the former exhaled before it could be elaborated to light. Now as thoſe flames of light could not ariſe from the ſpark which firſt kindled the heap, they muſt have been the luminous matter naturally condenſed in the vegetables; and this luminous part of the vegetables, exceeded the quantity of their opake matters, according to the proportion of the elementary matters, into which they were thus reſolved by incineration.

From this and other ſuch inſtances in the decompoſition of inflammable bodies, we cannot doubt of the conſiderable part the luminous matter makes in their conſtitution; but we ſhall be ſtill more convinced of it, if we conſider the great quantity of light abſorbed by every body, to which that ſubſtance has acceſs, and in which light muſt therefore become a concrete. The light of candles in a room immediately vaniſhes the inſtant they are extinguiſhed; and this happens as ſuddenly after they have burned for a conſiderable time, as if they were only lighted for an inſtant; the ſame may be ſaid of a fire, yet the heat will ſenſibly remain for ſome time after the fire is put out; muſt not then all the flood of light, with which the room was before replete, have been abſorbed by the walls and bodies in the room? Theſe bodies from the fire conceived a ſenſible heat; now heat and light being properties of the ſame matter, they muſt have gone together into theſe bodies, conſequently, their ſupporting ſubſtance muſt have gone along with them, and entered as a concrete into theſe bodies by which it was abſorbed. The cauſe of this abſorption has not yet been explained by philoſophers, but ſhall in future be taken into conſideration.

How much of this luminous matter then muſt be abſorbed by all the bodies expoſed to the ſunſhine, or the light of the atmoſphere during the courſe of a ſummer's day? How much during the time of their growth, or while they remain expoſed to the ſolar light? How much is abſorbed by the atmoſphere, and ſhackled down therein by the *vagum ſoſ-*

ſile, or at leaſt by ſome concentrating ſubſtance, to form the elaſtic matter or baſis of air? And how much of this luminous matter in this form enters into the compoſition of all bodies, as hath been explained in the fourth Lecture? We cannot therefore be ſurprized at the quantity of light which is contextured in all bodies by natural operations, and which again departs from them in their diſſolution, whether in the form of flame as in torrifaction, or of light as in putrifaction.

Now ſince we have ſeen in the laſt ſection, that ſalts poſſeſs a ſhackling and binding faculty, is it not natural to conclude, that it is the ſalts of bodies or the origin thereof, which confines in them that quantity of light or fire, which iſſues forth by colliſion or friction, and diſplays itſelf in electrical experiments, and that gives to that lively ſubſtance, which bodies contain, the conſiſtency peculiar to the elaſtic matter? For light, which we have proved to be a chief principle in the elaſtic matter, is of exploſive eſſence, and of a divergent centrifugal propenſity; whence it derives the power of dividing and reſolving bodies, of detaching and diſperſing their parts; whence alſo fire breaks and ſplits bodies, diſſolves metals, rarifies fluids, and volatilizes even the heavieſt and moſt denſe liquids to a degree of levity greater than that of air, in which they riſe and evaporate: conſequently, the ſubſtance of light or fire, being thus expanſive, is wholly unqualified not only for binding and cementing bodies, but even for aſſuming alone the adheſive form of the elaſtic matter, without the aid and union of ſome coercive principle to correct this centrifugal propenſity, and, if I may be allowed to ſay ſo, to connect and fabricate its parts, which ever tend to diverge and expand.

The neceſſity of a coercive matter to render light capable of the gradual, continuous, and (to uſe the expreſſion of the learned Bacon) bridled operation of the elaſtic matter, will be ſtill more apparent by remarking the contraſt between that inſtantaneous operation, which excites viſion, and the temperaneous propagation of that tremour or vibration, which generates ſound. The former we ſee exemplified in the ſudden flaſh of lightning, or of inflamed powder; the latter in the more ſlow and durable roar of thunder, or the report of a gun, which reaches a diſtant ear ſenſibly later than the flaſh has ſtruck the eye, which ſhews how differently that lively matter operates, when free and diſengaged in its native ſtate, and when connected and contextured with another body, whereby it is incapable of exciting viſion, and only ſuſceptible of the gradual vibratory motion which propagates ſound.

Of this we have another example in the flaſh of light and tremour, which are at once excited in ſtones, metals, and ſuch hard bodies by colliſion. The moſt lively part of the elaſtic matter, which is the fiery or luminous ſpecies, being diſengaged by the ſhock from the other matters of the body, and being reſtored to its native liberty and pure form, cauſes that inſtantaneous ſenſation of light; but the part of the ſame ſubſtance, which remains blended with, and bound down by the other matters of the body, is only capable of cauſing the more ſlow and eaſy operation of tremour. Now a phyſical cauſe is neceſſary to ſhackle down the innate activity of the luminous ſpecies, and to fabricate this ſubtile expanſive ſubſtance into a more adheſive and quieſcent matter; and for this change in its ſtate, what cauſe can be rationally aſſigned, except a different ſpecies of matter by nature coercive, which gives firmneſs to body, and which is the real cauſe of coheſion? An attraction indeed is treated of in our modern phyſics, which, like *vis inertiæ*, is attributed to all matter in general; and to this property are imputed even all exploſive operations, as well as thoſe that are coheſive; for inſtance, earthquakes, * vulcanos, and all other phænomena that depend on an expanſive cauſe. This philoſophy likewiſe ſuppoſes all bodies and matter to be compoſed of one and the ſame kind of elementary particles; in which caſe, every particle of matter muſt, at the ſame time, be endowed with the different powers that predominate in the works of nature, ſuch as attraction, expanſion, gravitation, and *vis inertiæ*. But, according to our theory, it is impoſſible for the ſame elementary particle to be endowed with different eſſences; conſequently, as oppoſite eſſences require different ſubſtances to ſupport them, it follows, that the inert particles cannot be either attractive or expanſive, and that the matter which is expanſive cannot be at the ſame time attractive. Having then exhibited a matter whoſe eſſence is expanſion, it cannot be either inert or attractive; and having alſo exhibited another kind of matter which is by nature inert, it cannot be either attractive or expanſive. But, again, the operations and phænomena of nature, exhibit an attractive, a convergent, or an adheſive cauſe; conſequently, this muſt be attributed to a kind of matter different from the two former, one of them being inert, and the other expanſive; for this cauſe of adheſion and convergence indicates an eſſence; now every eſſence muſt have an adequate ſubſtance, and no elementary ſubſtance can have different eſſences; therefore, as an attractive, a convergent, or an adheſive eſſence exiſts in nature, it muſt have a peculiar ſubſtance: conſequently, to prevent the multiplication of principles, we muſt conclude, that the ſource and origin of ſalt muſt be that adheſive ſubſtance, ſalt being the third kind of matter which ſhews itſelf in the decompoſition of body, and diſplays that power.

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* See Philoſophia Britanica on Attraction of Coheſion.

A large bell, notwithſtanding the coheſive firmneſs and thickneſs of its metal, will, in ringing, change from a circular form to that of a changeable elypſe, *i. e.* whoſe conjugate and tranſverſe diameters alternately interchange. This is at once perceptible to the ſight and touch, and may alſo be clearly inferred from the rebounding hum or buz that continues in the air after the ringing has ceaſed. The phænomenon is equally ſenſible in muſical glaſſes as well by the ſound, as by the tremulous agitation, which ſhoots in through the water on all ſides from circumference to centre, without occaſioning any change of place in either the firm or fluid ſubſtances, an effect evidently indicating the continuity and adheſiveneſs of the agent producing it; for unleſs the lively ſubſtance, which propagates the tremour, were really continuous, the propagation could not be performed without ſome tranſlation or change of place. The neceſſity of this continuity for real elaſtic tremours, is again proved in the converſe; for, as we have before obſerved, the ſmalleſt crack, either in metal or glaſs, which deſtroys the continuity of the elaſtic ſubſtance, will render it incapable either of melody, or of a lengthened ſound.

Seeing therefore, from a variety of proofs, that the context of the elaſtic matter is adheſive and continuous, and having alſo diſcovered from its operations that it poſſeſſes a contractive as well as an expanſive power, as no elementary principle can poſſeſs two oppoſite powers and propenſities, it neceſſarily follows, that the elaſtic matter, whoſe ſubſtance and operations have been ſo well aſcertained, is compoſed of two diſtinct elementary principles, to wit, the ſaline and the luminous, oppoſite in nature and propenſity. Something analogous to this had occurred as a rational conception, before we took into conſideration the formation and ingredients of glaſs, which realizes and experimentally exhibits a concluſion before founded on reaſon; for in it we have diſcovered that coercive ſpecies of matter, whoſe neceſſity is ſo apparent throughout all nature; in it we have diſcovered the operation of this coercive principle, which binds down in glaſs ſuch a quantity of fire, or of the expanſive principle, as renders that ſubſtance capable of repulſive tremours, ſonorous vibrations, and perhaps of tranſparency (by and by to be examined.) In glaſs alſo we diſcover that continuity of ſubſtance which proceeds from the perfect ſolution and intermixture of its component parts, which we have always inſiſted on in the elaſtic matter.

Thus glaſs, in its properties and compoſition, though not ideatically the ſame with the elaſtic matter, is a moſt perfect and clear repreſentation of that ſubſtance. No hard body is more elaſtic than glaſs; hence the quickneſs of its vibrations, and ſweetneſs of its ſound, which quality it derives from the quantity of fire in its compoſition. No hard body has a cloſer adheſion of parts, (diamond excepted) whence the firmneſs and keenneſs of the feather-edge it affords when broken; and this property is owing to the force and uniform diffuſion of the coercive or ſaline principle. No hard body is more void of pores, and has ſuch continuity of texture, whereby it is almoſt incapable of corruption, fit to contain the ſtrongeſt ſpirits, capable of reſiſting all menſtruums, and immutable in fire. This continuity proceeds from the perfect diſſolution of all its ingredients, and their uniform and perfect coalition in the ſtate of fuſion, which afterwards continues, when the fire ceaſes, and the whole becomes a firm but continuous maſs. The comparative excellence of diamond in all thoſe properties, is owing to the uſual ſuperioty of the operations of nature over thoſe of art.

We can at preſent, from the compoſition and ingredients of the elaſtic matter, determine a queſtion, which aroſe in the courſe of the fourth Lecture. Having ſeen, in the incineration of vegetables, that the numerous powers and qualities of thoſe bodies were all carried off in the form of flame and vapour, whoſe expanſive force diſengaged it from confinement, as ſoon as the conſiſtency of the body was deſtroyed by fire; it was a natural and philoſophical ſuppoſition that all theſe powers and qualities had proceeded from, and been ſuſtained by the ſubſtance, which they then ſeemed to accompany in its flight. It occurred, however, that although all the lively powers and qualities analogous to expanſion might have been produced and carried off by the elaſtic ſubſtance, yet that coheſion, gravity, and ſuch qualities as were oppoſite to expanſion, could not have belonged to that ſubſtance; wherefore we were obliged in ſome degree to depart from the opinion of Boerhaave. But being at preſent better acquainted with the nature and compoſition of the elaſtic matter, we are able to reconcile that apparent repugnance, from the different natures of the two elementary principles, of which the elaſtic matter is compoſed: for the oppoſite natures of thoſe two principles render the reſulting ſubſtance capable of ſuſtaining properties otherwiſe repugnant; it is not however to be imagined, that we conſider this ſubſtance as the immediate cauſe of coheſion and gravity; our opinion on this head ſhall appear in the ſecond part of this work; but for the preſent it appears evident, that the ſaline principle is always contextured with light in the elaſtic matter, reſtraining its expanſion, and fabricating its ſubſtance into a coheſive texture. Whether theſe elements, after their perfect coalition in one ſubſtance, afterwards diſunite and return to their native forms, is not yet to be determined: but we know at leaſt by the bitter, ſaline, and acid qualities of ſmoke, which alſo affect the eyes, that the elaſtic matter of every body is ſtrongly impregnated with the ſaline principle, before it aſſumes the more pure and exalted form of flame. It now remains to explain the phænomena and operations of elaſticity by means of this ſubſtance, whoſe nature and properties have been ſo fully explained.

SECTION IV.

Solution of Elaſticity. The Operation and Eſſence of the Elaſtic Matter explained; Definition of that Subſtance.

THE explanations of elaſticity hitherto given are ſo hypothetical and exceptionable, as ſcarcely to deſerve a refutation: we ſhall quote them from Chambers's *Cyclopædia*; (ſee *Elaſticity*.) "The cauſe or principle of this "important property, *elaſticity*, is variouſly "aſſigned: the Cartheſians account for it by "the *materia ſubtilis* making an effort to paſs "through pores that are too narrow for it. "Thus, ſay they, in bending or compreſſing "an hard elaſtic body, *e. gr.* a bow, its parts "recede from each other on the convex ſide,

" and approach on the concave: conſe-
" quently, the pores are contracted or
" ſtreightened on the concave ſide; and if
" they were before round, are now, for in-
" ſtance, oval; ſo that the *materia ſubtilis*,
" or matter of the ſecond element, endea-
" vouring to paſs out at theſe pores thus
" ſtreightened, muſt make an effort at the
" ſame time to reſtore the body to the ſtate
" it was in, when the pores were more pa-
" tent and round, *i. e.* before the bow was
" bent."

" Other later and more wary philoſophers
" account for elaſticity much after the ſame
" manner, with this only difference, that in
" *lieu* of the ſubtile matter of the Carthefians,
" theſe ſubſtitute Ether, or a fine etherial me-
" dium, that pervades all bodies."

To this opinion it may be objected, firſt, If theſe authors ſuppoſe the *materia ſubtilis* or Ether different from the baſis of air, the ſubſtance of light, or the electrical matter, which are one and the ſame, they ſhould aſcertain and prove its exiſtence. Secondly, As by it they explain the activity of other bodies, they ſhould alſo explain how itſelf acquires activity, or whence it derives its motion. Thirdly, They ſhould prove that all bodies which have an elaſtic ſpring are really porous. This we defy them to do, with regard to a thick well-poliſhed piece of glaſs, whether a priſm or lenſe; unleſs, contrary to the nature and rules of philoſophy, an arbitrary hypotheſis is to ſuperſede obſervation and experiment.

"Others" continues the abovementioned author, "ſetting aſide the precarious notion "of a *materia ſubtilis*, account for elaſticity "from the great law of nature, attraction, "or the cauſe of the coheſion of the parts of "ſolid and firm bodies.—Thus," ſay they, "when a hard body is ſtruck or bent ſo as "the component parts are moved a little "from each other, but not quite disjoined "or broke off, or ſeparated ſo far as to be "out of the power of that attracting force "whereby they cohere, they muſt certainly, "on the ceſſation of the external violence, "ſpring back to their former natural ſtate."

To this opinion we alſo object, that theſe authors pretend to explain one myſterious operation of nature by another equally obſcure: for the principle of coheſion is hitherto by no means diſcovered; and the preſent ſolution of that property by corpuſcular attraction is contradictory and inconſiſtent with the ſimplicity of nature. Corpuſcular attraction is a principle ſo univerſal, and at the ſame time ſo compliant, that, according to Mr. Martin, * it explains the phænomena of eruptions, earthquakes, vulcanos, and elaſticity, as readily and as naturally as it does thoſe of coheſion, ſoldering and glewing. Nor is this ſurpriſing, ſince, according to philoſophers, each particle of matter is at once endowed with an attractive and repulſive power, and at the ſame time inert. But the inconſiſtency of this notion has been touched upon in the preceding Lectures, for, in the ſecond we have ſhewn, that either of thoſe powers is inconſiſtent with inertneſs; and in the firſt, that thoſe powers, in the ſame particle of matter, are inconſiſtent with each other.

Beſides, hard firm bodies are aſſumed to explain an univerſal principle leſs remarkable

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* See the Philoſophia Britanica:

in hard bodies than in fluids, to which however the explanation is totally inapplicable. For what attraction of particles is adequate to the elaſticity of air, or the expanſion of fire, which will propel a ball from a cannon, with ſuch force as will ſplit a rock, and is capable of producing ſuch effects as accompanied the earthquakes of Calabria above deſcribed?

The hypotheſis which aſſigns the preſſure of the air as the cauſe of elaſticity, merits no attention: for a watch, or any machine actuated by a ſpring, will be found to continue its motions in *vacuo*, as well as in the open air.

Thoſe indeed who make the elaſticity of bodies proceed from the elaſtic force of the air they contain, have many experiments on their ſide, and are in approach to the truth; for the elaſtic matter, which is the true principle of elaſticity, is alſo the baſis of air, and muſt conſequently exiſt wherever air is inherent. But it is not this air, nor the looſe fire which electrical experiments detach from bodies that is the cauſe of their elaſticity; it is that *air*, that *fire*, or rather that elaſtic matter (for all theſe have one common principle) which is contextured with the other elementary parts of bodies during their growth and formation.

Fire either produces or improves elaſticity wherever it is employed. Water is by fire exalted into a moſt elaſtic vapour, as is clear from the Æolipyle or ſteam engine; for which reaſon, the ſolar heat occaſions evaporation. For the ſame reaſon, mercury, ſulphurs, and all metallic ſubſtances are ſublimated and put to flight by a ſtrong fire: the heat of an animal protrudes its exudations and perſpirations: the heat of the ſeaſon enlivens and ſends forth the odorific effluvia of flowers and vegetables; and, however great the elaſticity of air be, which has for its baſis the elaſtic matter, it is ſtill heightened by fire; conſequently, every body that incorporates air ſhould be rendered more elaſtic by fire; and this is the caſe with all bodies whatſover. By the power of fire likewiſe, crude ores get the conſiſtency of firm and elaſtic metals. By the action of fire, and the acquiſition of phlogiſtic or elaſtic matter, the ſofteſt iron gains the ſpring and firmneſs of ſteel; and by the heat of a ſtrong fire, or of the ſolar light concentred in a focus, all theſe ſubſtances are reduced to a vitrious matter, whoſe elaſticity is evidenced by the ſound and melody of muſical inſtruments compoſed of glaſs. From all which it follows that fire, if not the ſole, is at leaſt the principal cauſe of elaſticity in all bodies.

But as the elaſticity of moſt bodies is improved in their converſion into glaſs, this property, in other bodies, muſt neceſſarily be ſuppoſed to ariſe from the ſame principles, which concur to its production in that ſubſtance, which are fire and the ſaline principle; for, by an uniform mixture of theſe expanſive and coercive principles in any body, a third is produced in a mediocrity between the natures of both, that is, at the ſame time expanſive and coercive, or, to expreſs both in one word, elaſtic. From the nature of one of its components, the parts of this ſubſtance labour to expand, the other ingredient reſtrains their expanſion; and between theſe oppoſite exertions that tremulous motion is produced, which characteriſes the elaſtic matter: for any touch, impulſe, or excitation, on a part of this compound ſubſtance, will ſtimulate a motion in the expanſive parts, which would immediately fly off, were they not reſtrained and kept together by the coercive parts, which, reacting againſt the centrifugal propenſity of the expanſive parts, bring them together again; and this acceſs of the expanſive parts, is a new ſtimulation for their receſs, and produces that effect: whence proceed theſe alternations of receſs and return, which conſtitute a tremulous or vibratory motion throughout the parts of an elaſtic body. For we have ſeen that the elaſtic matter is inherent in all parts of elaſtic bodies; at preſent we underſtand this ſubſtance is every where compoſed of the expanſive and coercive matters uniformly blended and contextured together; conſequently, the firſt impulſe received, though but in one part, ſhould communicate a general excitation throughout the whole continuity of the elaſtic matter; and this general expanſion muſt immediately be as generally counteracted; ſo that the vibratory motion operates through the whole, or a great part of the ſounding or elaſtic body, whether firm or fluid, without diſturbing or diſplacing a ſingle part or particle from its relative ſituation.

This theory is fully conformable to experience, and ſeems to be the only theory which gives a ſatisfactory explanation of the phænomena both in firm and fluid bodies. When a bell is rung, waves of air are generated by the expanſive and convergent efforts of the elaſtic ſubſtance therein contained; and diffuſe on all ſides, according as theſe efforts are propagated throughout this active ſubſtance. This may be rendered more ſenſible by the viſible undulations of water. The number of waves, then, ſucceſſively riſing and diffuſing from the point, where a ſtone is plunged, clearly indicates the new ſtimulations of the expanſive matter, which ariſe from the reaction occaſioned by the returning efforts of the convergent. The relative reſt of all parts of the water, or their retaining their relative places, is proved by the quieſcence of a feather, or any other light body on the ſurface, and denotes the continuity and uniformity of the elaſtic medium in water, whereby its action is uniformly propagated, not by a tranſlation of parts, but by a continuous reiterated impulſion: the ſame in every particular may be ſaid of the ſpherical waves excited and propagated in air by the tremours of a ſounding body;

without diſplacing any particle of the air; and the ſame explanation is likewiſe applicable to the elaſtic tremours which are propagated through all parts of the ſounding body, with a change of figure, but without any change of place in its component parts or texture.

The power of this ſubſtance to diffuſe metals of different ſpecific gravities throughout each other, to blend them equally in all parts, and to unite them in one uniform maſs, diſplays at once its *expanſive*, *continuous*, and *adheſive* properties. The ſame properties alſo manifeſt themſelves in its power of diffuſing through water the ſenſible qualities, and medicinal virtues of vegetables and animals, which it had ſuſtained and nouriſhed in thoſe bodies, while inherent in them; but which it alſo retains and carries with it, when by coction it is transfuſed into water; for it is by the expanſive property that it is diſlodged and tranſpoſed; by its continuity that it equally and uniformly impregnates the water in all parts; and without the binding property it could not transfer and retain its qualities, for they would be otherwiſe volatilized and excluded by the expanſive and penetrating power of heat or fire, which is the inſtrumental cauſe of their tranſpoſition.

Now in order to form our definition, the ſubſtance and eſſence of this univerſal principle may be well expreſſed by the name *elaſtic matter* ; for although it be ſeemingly neutral and latent in all bodies, yet it is always the cauſe and conſerver of their elaſticity and vigour. For the ſmalleſt agitation, which deſtroys its dormant neutral ſtate, makes it impart to the body, in which it reſides, a ſpring and reſtorative power, to regain its original ſtate ; as we have ſhewn in our Lecture on this head.

Beſides elaſticity, this matter, according to Boerhaave, is of a binding and ſtrengthening nature, which it derives from the coërceive matter which is one of its components. It is the baſis of powers, qualities, and medicinal virtues, in foſſils, vegetables, and animals ; as we have proved in the mixture of metals, and tranſpoſition of qualities from body to body, in which it is the vehicle : we have proved the ſame in the inſtances of fuſion and torrifaction ; whence its utility and neceſſity in mixing and binding bodies together, in conſolidating ores, and refining metals, and in changing iron to ſteel by impregnating it with phlogiſton. This ſubſtance, which is in fact nothing but our elaſtic matter under another name, is obtained from vegetable and animal bodies, when purged by fire of what chymiſts call their *phlegm* and ſulphureous acids, the phlogiſtic vapour, then emitted by them, gives to iron elaſticity and hardneſs.

As this elaſtic matter, or, as Boyle ſtiles it, elaſtic ſpecies is a ſubſtance eſſenced with qualities peculiar to and depending on its two component elementary ſubſtances; notwithſtanding its being a compound ſubſtance, it merits the name of principle. Species is too futile a name for it, but may be applied to its detached or emanative parts, as in electricity. Theſe emanations are only fugitive or adventitious parts, which the body might have acquired from the influent light or air, and which it loſes again, when they are collected and agitated by rubbing, or a ſlight warmth incapable of affecting the texture of the body, and ſimilar to that which ſends forth the odours of vegetables in ſummer, or the eaſy perſpiration of animals.

The electric celerity of the fugitive ſpecies in theſe two inſtances, is clogged by the humidity; wherewith the emanations are loaded; and ſo alſo the force of gunpowder is reduced by moiſture.

But, on the other hand, we ſee that heat friction, or colliſion, ſhocks the parts of a body, ſo as to rouſe the latent matter, and give it motion and tremours towards the fricted parts, where it collects and compacts to ſuch intenſity as to give a ſenſation of light, and at length produce fire and flame; as we have ſeen in the conflict of hard bodies, where the operative cauſe is evidently the friction, colliſion, or fire there applied. But in air, water, and fluids in general, it is not ſo eaſy to determine the operative cauſe which produces the motion, collection, and intenſity of this matter, to cauſe winds, meteors, and ſtorms which are to be examined hereafter.

When this elaſtic matter is, by friction, colliſion, or the application of fire, kindled to a conſuming flame, it then acquires the ultimate degree of expanſion and vigour, by diſengaging itſelf in ſome meaſure from the ſhackles of the adheſive principle, changing into light its original form and ſtate, when created to warm and enliven the primordial matter: but as long as the luminous matter remains contextured with the coercive, ſo as by a perfect ſolution and intermixture of both (ſimilar to that of metals in fuſion, or of different liquids mixed together in one uniform fluid) to form the continuous poreleſs, and uniform ſubſtance called the *elaſtic matter*; ſo long this ſubſtance remains quieſcent through an *equilibrium* between the powers of its component principles, and exerts no action, until excited thereto by ſome external cauſe. But being thus acted upon, a peculiar operation of this ſubſtance is produced, ſuitable to that particular ſpecies of elaſtic matter, or conformable to the nature and violence of the acting cauſe. By which means the various effects already enumerated, to wit, *elaſticity*, *tremour*, *electricity*, *light*, *fire*, and *flame*, ariſe from the ſame generical principle, according to its accidental varieties, or exciting cauſes.

Having now, in the courſe of this Lecture, cleared our doubts concerning the *texture* and *eſſence* of this univerſal principle, and by a more ample inveſtigation of its properties, ſolved the phænomena of elaſticity, it is very fortunate to find that the *nature*, which has thus come to light, is, not only adequate to, but even obviouſly productive of all the operations and effects before aſcribed to the elaſtic matter; ſo that here ſubſequent diſcoveries illuſtrate and confirm thoſe which preceded.

In the preceding Lectures, we have eſtabliſhed the exiſtence and univerſality of this ſubſtance, and have pretty fully enumerated and explained its operations and effects; we have likewiſe ſhewn it to have been admitted by the moſt able philoſophers as an obſcure, indeed, but univerſal and efficacious *principle*; it now remains to cloſe our inveſtigations on this ſubject, by collecting our principal diſcoveries into an extenſive and well-founded definition; a method, which, if univerſally adopted and purſued, will, in time, introduce into phyſics that perſpicuity, certainty, and preciſſion, which have hitherto been confined to mathematics alone.

Definition of the Elaſtic Matter.

The elaſtic matter is a ſubſtance compoſed of two elementary principles, to wit, the expanſive and the coercive, ſo blended and contextured together, as to form one homogeneous and continuous ſubſtance. Its eſſence conſiſts in a double power of expanſion and convergence; which it derives from the diſtinct eſſences of its two components; and which may be expreſſed by the name *bridled expanſion* (a term borrowed from the great Sir Francis Bacon.) One of its principles is the material cauſe of coheſion, the other the ſource of expanſion and fluidity; and the exertions of both, when excited to action, produce the phænomena of elaſticity and tremour. This compound ſubſtance is the baſis of all lively material powers and qualities. Its activity is invigorated by heat, reſtrained by cold, but reduced and enfeebled by moiſture.

LECTURE VII.

On the Propagation of Light; on its tranſmiſſion through diaphanous Bodies. The Communication of Heat; and the Solution of Tranſparency.

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SECTION I.

On the Motion, Texture, and Propagation of Light.

IT has been juſtly conſidered as an unſurmountable difficulty to reconcile the tranſparency of bodies with their denſity; but particularly, with that poreleſs continuity, which the teſtimony of our ſenſes, and every kind of phyſical reaſoning requires, we ſhould attribute to glaſs: for the penetration of bodies, except where one opens and yields a paſſage to another, is inconſiſtent with the univerſal and eſſential properties of all matter, to wit, ſolidity and extenſion. Now glaſs has been proved by experiment to be void of pores; if then it tranſmits light, as it evidently appears to do, two bodies muſt occupy the ſame place; or, if this be impoſſible, as it is juſtly deemed to be, ſince the tranſmiſſion of light ſeems inconteſtible, it will follow, contrary to the moſt clear and accurate obſervations, that glaſs is really porous.

Here a principle, founded on reaſon and eſtabliſhed by analogy, is in direct oppoſition with a fact aſcertained by the moſt clear evidence of our ſenſes. Doubtleſs both cannot be true, both however are founded on principles of ſcience, and ſources of human knowledge; ſhall we then reject one, or reject both? To reject one, ſince both ſeem equally evident, would be deciding a queſtion by caprice rather than conviction; and to reject both, would be renouncing every ſource of philoſophical knowledge, introducing ſceptiſciſm into every ſcience, and bidding adieu to the moſt noble employment of the human mind. Let us therefore rather continue our inveſtigations, in hopes of coming at truth. Nature is ſimple and conſiſtent with herſelf; all the diſcoveries we make in her operations are therefore reconcileable, provided we diſcover the real cauſes. Imaginary or aſſumed cauſes may be inconſiſtent and contradictory; and their inconſiſtency is a proof of a miſtake; but the real cauſes are ſimple, uniform and univerſal, which characters are a clue for their inveſtigation, and a teſt of their reality, when diſcovered.

The preſent dilemma is pretty ſimilar to that which formerly exerciſed the ingenuity of philoſophers, and occaſioned the diſagreement between the abettors of the Ptolemaic and Copernican ſyſtems. The former objected to the diurnal motion of the earth, the ſtability of houſes, trees, men, &c. and pleaded both reaſon and obſervation to ſhew, that if the earth revolved about its axis, every thing would fly off, like clods from the wheel of a carriage, or a ſtone from a ſling: the latter urged the ſimplicity of nature, the analogy from the other planets, &c. Thus forcible arguments were played off on both ſides, without convincing the diſputants, or improving the ſcience. At length, however, the ſagacious Kepler diſcovered the properties and law of gravity, by which the objections of the Ptolemeans were done away, and the Copernican ſyſtem gained eaſy admittance; ſo that the ignorance of gravity, (whoſe cauſe, by the way, ſtill remains extremely obſcure) was the ſource of this inconſiſtency in ſcience, and difficulty in the explanation of nature. In the ſame manner, ſome wrong prejudice haſtily adopted, or ſome miſinterpretation of the facts apparently ſo clear, muſt be the ſource of the preſent difficulty; wherefore, to guard againſt both, we ſhall examine all parts of the ſubject with the utmoſt caution and diligence; conſidering firſt, the nature of light, ſecondly, the texture of tranſparent bodies, and thirdly, the mode of tranſmiſſion, or the communication of light through diaphanous bodies.

When a candle is lighted in a room, the walls and ſurrounding bodies are inſtantaneouſly illuminated; a flaſh of powder at night, will, in the ſame manner, illuminate the atmoſphere to a great extent; and lightening will ſpread its inſtantaneous gleam to a ſtill greater diſtance: but what is ſtill more remarkable, neither glaſs, water, nor any other tranſparent body will interrupt this ſubitaneous diffuſion of *lumen*. The queſtion is, therefore, whether the matter of light ſo diffuſed from the flaſh of powder or lightning, be really projected and tranſmitted through the atmoſphere, the glaſs windows, and other diaphanous bodies, to the bounds of the illuminated ſpace. This is the reigning opinion: it has received the ſanction of Sir Iſaac Newton's authority, and is delivered in theſe words by the author of the *Philoſophia Britanica*. * "Light conſiſts of inconceivably ſmall particles of matter of different "magnitudes, which are emitted or reflected "from every point in the ſurface of a luminous body, in right lines, and in all directions, with an unparallelled velocity;" this velocity he ſhews to be ten thouſand times greater than that of the earth in her orbit, or above a million and an half times greater than that of a cannon ball, which would go through 578 feet in a ſecond of time: he calculates it to be about 170,000 miles in a ſecond, *i. e.* near 680,000 times ſwifter than ſound: whence he infers the extreme ſmallneſs of its particles, to which, however, he attributes different magnitudes, ſo "that the comparative terms greater and leſs "are as applicable to the particles of light, as "to any other bodies." However, he lays ſo much ſtreſs on the extreme ſubtility of the particles of light, as to declare, (2 vol, p. 271) that "without this qualification, it could not "have pervaded the pores of bodies, and ſo "we ſhould have none of theſe which we "call diaphanous or tranſparent, and every "thing but the ſurface of body would have "been concealed from the ſight of man- "kind."

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* See Lecture on Light and Colours.

But this opinion is ſubject to ſerious difficulties, which, though repeatedly oppoſed to Newton and his followers, have never yet been liquidated by either. I ſhall quote ſome general ones from Dr. Hook, an Engliſh philoſopher, and a cotemporary of Newton, but ſomewhat his predeceſſor in the literary world.

"Firſt, * It is hard to conceive how ſuch in- "finitely ſmall bodies ſhould, with ſo rapid a

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* See the Poſthumous Works of Robert Hook. Lectures of Light, read in 1680.

" motion, paſs ſo vaſt a ſpace in an inſtant " almoſt, and yet, in every point of diſtance, " meet with croſſing ſpherical ſurfaces of " light" (from the ſtars, I ſuppoſe and reflecting planets) " and yet not be impeded or " ſtopt.

" Secondly, It is not as yet proved that " there is any ſuch thing as a *vacuum* in nature.

" Thirdly, Though it might be granted " that there was an extenſion without a body " to fill it, and a perfect vacuity; and " ſo the atoms or bodies moved through it, " will paſs without any impediment from " this medium or ſpace, yet, ſince we ſee " that light paſſes the moſt ſolid bodies alſo " inſtantaneouſly, or in a velocity rapid be" yond imagination; here certainly it ſhould " meet with impediments to ſtop it: for we " find it paſs through the hardeſt in the " world, namely, a diamond; and it ſeems " to paſs more freely through it than through " the air or water, or the moſt fluid body; " as may be gathered from the greater re" fraction of the rays from the perpendicu" lar, in the more ſolid body. Nor can I " conceive how the vacuity of the pores of " the bodies can ſolve this difficulty, ſince it " will be hard to conceive how thoſe pores

“ can be alike open on every ſide to the “ paſſage of the atoms of light,

“ Fourthly, ſuppoſing ſuch a vacuity or “ medium not reſiſting motion, and that “ there were ſuch bodies as atoms to be “ moved in it; yet it is difficult to conceive “ how they ſhould receive ſo rapid a motion “ from the luminous body: for no ſuch “ rapid motion is there in being. Now ’tis “ a rule, *nil dat quod non habet*, that which “ hath no ſuch rapid motion cannot give it “ to the atoms proceeding from it. Now “ that it is not neceſſary a luminous body “ ſhould have ſo rapid a motion, may be ar- “ gued from the ſhining of a diamond in “ the dark, only, by gently ſtriking it with “ the end of one’s nail, as I have often expe- “ rienced upon a large diamond that had “ that quality, or from the ſhining of rotten “ wood, or ſuch other cold ſubſtances, which “ ſeem not to have any ſuch kind of rapid “ motion, and yet produce light, which “ might be further inſtanced in the new “ phoſphori.

“ Fifthly, If ſuch a rapid motion of fiery “ atoms ſhould be the cauſe of light, it would

" be very difficult to conceive, how ſo ten-
" der a part as the eye ſhould continually
" receive them concentrated in the *tunica re-*
" *tina*, and yet not be deſtroyed and bat-
" tered to pieces by ſuch continual volleys of
" atoms."

" Sixthly, if there were ſuch a conſtant
" emanation of atoms, and that it has conti-
" nued ſince the creation of light, certain-
" ly this ſuppoſed *inane*, or void ſpace be-
" tween the celeſtial bodies, muſt needs have
" been filled quite full long before this, and
" then the free and inſtantaneous motion of
" the ſucceeding emanations muſt have
" ceaſed, becauſe they muſt find their way
" all ſtopt up by others, and conſequently,
" by this time we ſhould have no light at all
" communicated by the ſun.

But to come to conſiderations more pertinent to the preſent inquiry, every phyſical theory admits, and conſtant experience proves, that even bullets diſcharged by the force of artillery, are affected by the reſiſtance of the air, and that, not in the ſimple, but in the duple ratio of the velocity of the moving body; for, if only one particle of air was to reſiſt, reaction being equal to action, its reſiſtance would be in proportion to the velocity of the moving body; again, in a medium where there are many particles, the reſiſtance will be as the quantity of reſiſting matter the body meets; but the faſter the body moves, the greater quantity it meets: that is again, the quantity of reſiſting matter is as the velocity; therefore, from both conſiderations, the reſiſtance will be as the ſquare of the velocity: hence it is that a leaden bullet ſhot into water, is flattened as effectually as if it were ſtruck with a ſledge, whereas, if it be thrown into the ſame medium with a moderate velocity, it will neither receive any impreſſion, nor be ſenſibly reſiſted.

There are likewiſe other circumſtances, which influence the reſiſtance of a medium; for inſtance, the reſiſtance is great in proportion as the medium is denſe and tenacious, and as the moving body is large or extended; but it is alſo to be remarked, that the more denſe the moving body, the leſs it ſuffers from reſiſtance; for the reſiſtance is as the quantity of ſurface, but the force of motion is as the weight of the moving body, the former of which leſſens as the ſquare, and the latter as the cube of the diameter: from all which it follows, that when bodies are equal in weight and magnitude, in the ſame medium their reſiſtances are as the ſquares of their velocities, *i. e.* putting R for reſiſtance, and V for velocity, R as V^2.

Again, where the moving bodies differ in magnitude, all other things remaining the ſame, their reſiſtances are as their ſurfaces, that is, as the ſquares of their diameters. Putting then D for diameter, it will be in this caſe, R as D^2

Therefore, from both caſes, it will be R as $V^2 \times D^2$.

Again, the force of a body's motion in free ſpace, is as its quantity of matter into its velocity; but the quantities of matter of different bodies of the ſame denſity, are as the cubes of their diameters; therefore putting F for force of motion, F will be as $D^3 \times V$.

Conſequently, the force wherewith bodies of the ſame denſity, but differing in magnitude, move through or pervade the parts of the ſame medium, with different velocities, will be as $\frac{D^3 V}{D^2 V^2}$ *i. e.* as $\frac{D}{V}$ that is, their pervading forces will be as their diameters, divided by their reſpective velocities.

Now, if the pervading force of a leaden bullet, whoſe diameter is an inch, be ſuch as will make it paſs through our air 200 yards in a ſecond of time, what ſpace, in that medium, ſhall a particle of light paſs through, whoſe diameter is but the thouſandth part of an inch, and whoſe velocity we ſhall only ſay, is a million times greater than that of a bullet? (Mr. Martin eſteems it a million and an half times greater.) According to this theory, it will deſcribe five million times a leſs ſpace than the muſket-ball ſuppoſed: for $D : d :: 1 : \frac{1}{1000}$ and $V : v :: 1 : 1000000$; but the pervading forces are as $\frac{D}{V} : \frac{d}{v}$ *i. e.* as $1 : \frac{1}{1000000000}$.

And where the medium is the ſame, and the time the ſame, the ſpaces gone through will be as the pervading forces. Now the bullet goes through 200 yards in a ſecond of time; therefore, the particle of light, ſuppoſing it of the ſame ſubſtance with the bullet, will, in a ſecond of time only paſs through a ſpace equal to $\frac{200}{1000000000} = \frac{2}{10000000} = \frac{1}{5000000}$ *i. e.* the five millionth part of a yard. Where now is the ſuppoſed *tranſition* of light through our atmoſphere?

Again, where a body moves through different mediums, the reſiſtance it meets with ſhall be as their denſity and tenacity conjointly; now water is 800 times more denſe than air; conſequently, though it did not exceed air in tenacity, light would meet with 800 times more reſiſtance in it than in air; yet we find that both are inſtantaneouſly illuminated; can this be effected by the mode of *tranſition*?

Hitherto we have ſuppoſed light, however ſmall its particles, to be of the ſame ſpecific gravity with lead; but if now to minuteneſs we add levity or rarity, the loſs of motive force will be much more remarkable. For this we have no preciſe ſtandard, but from general obſervation, weight ſeems totally unimputable to light, (whatever reaſons are alledged for the contrary opinion ſhall be examined in their place) but for the preſent to illuſtrate the matter in a general manner, let fine feathers or down, minced as ſmall as poſſible, and in their looſe form be diſcharged from a muſket, to ſee how far they will proceed in air. To form a proper judgment, their progreſs ſhould be obſerved only from the time they begin to ſeparate and expand; for the expanſive and diffuſive propenſity of light, is another circumſtance inimical to its pervading motion. To conceive this more fully, it muſt be obſerved that whether light be allowed to be void of weight or not, at leaſt, as the cauſe of rarifaction in all other bodies, it muſt be exceedingly more rare than any other ſpecies of matter; and this is the greateſt of all its impediments in making a paſſage through air, a medium many degrees denſer than itſelf; for at the loweſt computation, the rarity of light muſt exceed that of air, in a greater proportion, than the rarity of air exceeds that of water.

Let then an experiment be made by diſcharging an air balloon, or any body of that rarity into water. A leaden bullet, with the velocity that powder gives it is flattened by reſiſtance, before it makes a paſſage of 20 inches in water; a ball of air then, with the ſame velocity, would not penetrate at all; much leſs would it with a greater velocity; for reſiſtance increaſes in the duple ratio of the velocity, whereas the moving force only increaſes as the ſimple velocity; conſequently, when the velocity is increaſed, the reſiſtance riſes in an higher proportion than does the pervading force; ſtill leſs would this air penetrate if ſcattered and unconfined: conſequently, the light or ſpecies of a candle-flame, of powder, of lightening, or that of the ſun, does not pervade the air to any ſignificant diſtance, not perhaps to the millionth part of the diſtance, to which the luminous gleam extends.

Nor is this the only ſide on which the preſent doctrine of light ſeems exceptionable. Its pervaſion through diaphanous bodies, and its being compoſed and propagated in diſtinct particles, are conſequences of the preſent ſyſtem of pores and corpuſcles, founded on the Epicurean principles of *vacuum* and atoms, of which later philoſophers have been too much enamoured. But, as the former motion is contrary to reaſon, the latter is contrary to analogy; for, in other ſolid and fluid bodies, as far as experiment can reach, particles are rather the object of imagination than of ſenſe, and are frequently as hypothetical as the points into which a line is diviſible; which may indeed ſerve to fix the attention, or illuſtrate ſome idea, but can never be ſuppoſed real and diſtinct components in the line. In order to aſcertain the truth of this remark, if we examine the ſtate of that body of light which ſurrounds a candle or any other luminous body, we find it extends on all ſides, as from a centre; being on every ſide, and in every direction, equally intenſe at equal diſtances from the central flame. Beſides, philoſophers agree upon theſe two points, to wit, that it's intenſity at different diſtances from the luminous body is always in the inverſe duplicate ratio of the diſtance; and that there is not a point within the bounds of the illuminated ſpace, even at the moſt attenuated part, void of light; with this difference however, that, according to the aforeſaid ratio, any given ſpace, ſuppoſe that which the head of a pin would occupy, at a certain diſtance from the illuminating body, ſhall have an hundred times more light than would the ſame ſpace have at ten times that diſtance; yet, at this greater diſtance, the matter of light is as equally and as evenly diffuſed, as at the very ſurface of the luminous body, from which it iſſues alike at all parts, while at all parts the flame is equally vigorous and unreſtrained: and this being the caſe with the ſun, we have reaſon to conclude, that the ſpecies of light is as equally and evenly diffuſed at the remoteſt part of the immenſe ſphere he illuminates, as at his ſurface, where that ſpecies is moſt intenſe. For there is not an aſſignable point at the verge of that illuminated ſphere, in which an eye will not ſee the luminous body. There is not, therefore, a point in that luminous ſphere to its termination void of light. Conſequently, the light that fills this ſpherical ſpace, muſt be a *continuum*, that is, not compoſed of diſtinct particles, but a flowing ſubſtance void of pores.

To reaſon mathematically on this ſubject (for mathematical reaſoning is allowable in phyſics, when applied to its proper objects, to wit, *number*, *dimenſions*, *quantity*, &c.) If light be emitted from the ſun in diſtinct particles, theſe cannot be ſuppoſed cloſer at his ſurface than to touch; therefore, as they are ſuppoſed to diverge, at the diſtance of a yard from the ſun, they are no longer in contact, but have a real, though not a perceptible interval between them. And ſince the rarity of light increaſes in the duplicate ratio of the diſtance, from the ſimilarity of triangles, the intervals between any two contiguous rays, at any diſtance, muſt be directly as that diſtance from the luminous body; conſequently, at the diſtance of a thouſand yards, *i. e.* at half a mile's diſtance from the ſun, the interval between them will be a thouſand times greater: now ſuch intervals ſhould be in ſome manner ſenſible, but much more ſo at 8000 times that diſtance, *i. e.* at the diſtance of a ſemidiameter of the earth from the ſun: but, according to Kepler, our mean diſtance from the ſun is 34377 ſemidiameters of the earth; how very great then ſhould the intervals between any two contiguous rays of light be at the ſurface of the earth? Certainly, in this caſe, the intervals ſhould be ſo great here between contiguous rays, as would leave ſmall objects, ſuch as a pin's point or its head in obſcurity, for want of light that would render it viſible, which is contrary to experience; therefore light is not in the form of particles.

For we find by experience, that wherever ſuch a point is preſented when the ſun ſhines, it will meet and reflect not only a particle, but millions of particles, for it will be viſible at ſo many different points, as a perſon may diſcover by viewing it through a microſcope, from every point of ſpace around it where he will not obſtruct the light. This reaſoning may be rendered ſenſible, by drawing as great a number of rays as poſſible from the centre of a circle to the circumference. For, however the number of ſuch rays be multiplied, according as they extend from the centre, their divergence will increaſe; and the interſticial ſpaces will ſoon exceed the breadth of the rays: for it muſt be obſerved, that the rays made uſe of to illuſtrate this matter, muſt not be pure mathematical lines; they muſt have, and be ſuppoſed to have breadth, otherwiſe they could not repreſent rays of light, which, according to Sir Iſaac Newton, have not only magnitude and dimenſions, but alſo *different ſides*, endowed with oppoſite powers.

Since, then, no pore or void interſtice can be found, or juſtly ſuppoſed, in the whole globular body of light which ſurrounds the ſun, that ſphere of luminous matter is in all parts perfectly continuous, and on all ſides equally denſe, at equal diſtances from the luminous body. Again, we find that a candle or lamp, if equally ſupplied with fuel, and uniform in the vigour of its flame, will conſtantly and uniformly maintain the ſurrounding ſpace replete with light; the extent of this illuminated ſpace will be proportioned to the vigour and magnitude of the flame; but, whatever be its extent, it will remain permanently full, as long as the luminous effuſions continue to iſſue forth. Nor is any increaſe or diminution of denſity or luſtre perceptible or admiſſible in any part of this ſpace, from the moment it is illuminated, until the flame be extinguiſhed, provided the magnitude and vigour of the flame remain unvaried. Conſequently, as this is the caſe with the ſun, whoſe magnitude and vigour are always the ſame, we muſt by analogy conclude, that the whole ſpherical ſpace which he illuminates, is, and has always been, permanently and equally full of light, ſince that glorious body was placed in the centre of the univerſe, to enlighten, cheriſh, and enliven his ſyſtem of planets.

What has become of the ſolar emanations during ſo many thouſand years already elapſed (his light and heat not being more powerful upon the earth at preſent, than a thouſand years ago): as alſo how his vigour is permanently ſuſtained: or by what *pabulum* his perpetual effuſions and waſte of ſubſtance are ſupplied: theſe are queſtions which deſerve more attention than philoſophers generally beſtow upon them, but which the limits preſcribed in this inquiry will not permit us here to examine, we muſt therefore reſerve them for the ſecond part of this Work. We ſhall only remark, that if the vaſt expanſe wherein the planets move had been a perfect vacuum, when the ſun was firſt placed in its centre, it could not continue ſo long: for ſurely a ſpace ſo replete with ſolar matter as not to admit the ſuppoſition of the ſmalleſt vacuity or interſtice, cannot be called a *vacuum*, but rather a *plenum*, in the ſtricteſt ſenſe.

And ſince the filling up of any ſpace with a fluid from a fountain ſituated in any part thereof is a material effect, ariſing from a material cauſe, time is neceſſary for its production: therefore, as a new made pond requires time to be filled up by a ſpring in its centre, or a ſtream flowing into it, ſo the vaſt illuminated ſpace about the ſun, after that body was created and fixed in its centre, required time to be repleniſhed with his effuſions. And as the pond, whenever filled, is, by a conſtant acceſſion of water from the ſource, kept permanently full; in the ſame manner, the plenitude of luminous matter in the vaſt expanſe, ſince it hath been originally filled by the ſolar effuſions, is held up in all parts thereof, by a conſtant acceſſion of new-born matter, flowing *in continuum* and *in orbem*, not with that inexplicable projectile velocity of 170,000 miles in a ſecond, *i. e.* a ſpace equal to the earth's diameter, in leſs time than the twentieth part of a ſecond; but in a conſtant and continuous flow, like that of water, which keeps the pond full, or that of candle-light in a room, either of which muſt be removed before the ſucceeding effuſions can paſs towards the limits of their reſpective ſpaces. . . . .

From the waſte of a candle or taper, we know that the tallow or wax is ſucceſſively transformed into the flame which conſumes it, and thence expended in effuſions of light. We alſo know from experience, that the light once diffuſed throughout the room is not increaſed by the ſucceeding effuſions, but is as intenſe and ſtrong the moment after illumination, as after a number of hours. Since then light does not increaſe by the ſucceſſive effuſions of the flame, theſe effuſions muſt vaniſh at the bounds of the enlightened ſpace, where walls and other opake bodies abſorb the light as faſt as it iſſues forth. But, for this purpoſe, the light of the whole ſpace muſt be in motion from the centre of the flame on all ſides, *in orbem*, with a centrifugal propenſity towards the ſurface, ſo that every part or particle of light retains its relative place with regard to thoſe which precede and follow. For a ſubſequent effuſion not having a greater force or velocity than that which immediately precedes, can only follow the former in its natural order, and with the ſame common motion; and even though it were ſuppoſed to iſſue forth with a greater force than did the former, which is a falſe ſuppoſition, the ſpace being already filled, this could only avail to protrude the already moving fluid with a new impulſe; and ſince the effuſions of the ſun, or of any other luminous body, as, for inſtance, the flame of a candle, are emitted, propelled, and get motion by the expanſive vigour of that body, all the emitted ſpecies will continue in the direction and motion ſo received; this being ſo throughout the whole body of the luminous ſpecies, which, in all parts is flowing from centre to ſurface *in orbem*, no other force is neceſſary to preſerve that motion.

This theory may be again illuſtrated by the ſpherical waves of air, or of its elaſtic ſpecies, which expands on all ſides from where it is agitated by the tremours of a ſounding body, with this difference however, that light flows thus in *orbem*, but conſtant, without intermiſſion, in uniform ſucceſſion, we may ſay, like time. The cauſe of this difference is, that the ſpherical waves of air are not occaſioned by the ſucceſſive generation and diffuſion of a new ſpecies, which afterwards vaniſhes; for the elaſtic ſpecies of the atmoſphere is permanent, and its waves ariſe from the tremours of the ſounding body, which communicate an impulſe to the air, which being reſiſted by the ſtagnate and remoter parts, the action and reaction cauſes a vibratory undulation. But, on the other hand, the new-born ſpecies of light, when emitted and urged forward by the expanſive vigour of flame, is neither reſiſted nor retarded by what went off before it, *that* having received its motion from the ſame power, as will alſo *that* effuſion, which is next to follow from the flame. Thus, if the emanating ſpecies were divided into parts, as time is divided into moments, the former would follow in ſucceſſion like the latter, without any poſſibility of changing their relative places, but would flow in a *continuum*, without interval or interſtice, becauſe they vaniſh in the ſame order in which they came into exiſtence; and alſo like time, which is ever preſent, though in conſtant ſucceſſion; ſo this body of light, though ever flowing from the ſun, is ever preſent in all the parts of the vaſt expanſe which he illuminates, except where opake bodies intervene.

Since, therefore, no part is ſtagnate, either near or remote, and no part meets with curb or reſiſtance from its own ſpecies, ſo as to form a tremulous motion, the action of this fluid muſt be ſwifter than any other that is ſubject to ſuch reſtraints; which accounts at once for the immenſe celerity, unremitted propagation, and rectilineal direction of the illumination. The firſt and ſecond of theſe properties are owing to the prodigious expanſive force of the ſun, and this uniform and uninterrupted ſucceſſion of his emanations; for, on this account, the vaſt *expanſum* is continually replete with ſolar matter, proceeding from the ſun with unchangeable motion, and impreſſing the ſenſation of light and viſion, wherever an eye becomes expoſed to the impulſe of this uninterrupted flood, that is, the inſtant the opake body is removed which intercepted its continuity. The rectilineal direction of light proceeds from the perfect continuity of the whole flood of ſolar matter; for there being no interſtice or vacuity throughout the whole extent of its diffuſion, but this flowing ſubſtance being a perfect *plenum*, each and every part muſt retain its relative place, and original determination, without ability to deviate therefrom. Nor will its rectilineal courſe be altered by the intervention of an opake body; for this ſubſtance is not tenacious or adheſive, but of a quite oppoſite nature, *viz.* expanſive and divergent; it will not therefore in its progreſs, like waves of water, bend round obſtacles, no more than if it were in the form of diſtinct and detached particles, propelled in right lines from the ſun.

From the whole of this natural inveſtigation it appears, that light is neither communicated through tranſparent bodies by *tranſition*, nor compoſed of diſtinct particles, but a flowing body, whoſe parts are in ſucceſſive generation and conſumption. Its motion is *in orbem*, and its motive force is the expanſive vigour of the luminous body, by which it is emitted and protruded, not by diſtinct impulſes, but a conſtant and ſucceſſive preſſure of the new-born matter, iſſuing from its ſolar fountain, or any other luminous body.

SECTION II.

The Cauſe of Continuity in Glaſs. Light not tranſmitted by Pores. Porous Hypotheſis groundleſs.

IN the preceding Section, we have examined one part of the preſent hypothetical ſolution of tranſparency, and have found, that the ſuppoſed tranſition of particles of light through pellucid bodies is inconſiſtent with the phænomena of light, and laws of reſiſtance; but to bring the ſubject to a more ſatisfactory iſſue, and to facilitate the diſcovery of the real mode of light's communication through tranſparent mediums, we ſhall now conſider the phænomena of tranſparency, and collect as much information as poſſible from them, and from the obſervations of other philoſophers, but particularly Newton.

It is a known fact, that glaſs is tranſparent, and that vegetables in general are opake; it has appeared however, in the courſe of this Work, that both are compoſed of preciſely the ſame materials, or elementary ſubſtances, *viz.* earth, light, and a fixed alkaline ſalt. This proves that tranſparency does not proceed ſolely from the light contextured in glaſs, as we have ſomewhere hinted, but that a certain diſpoſition of the component principles is likewiſe neceſſary; for, when the conſtituent matters are identically the ſame, from what, but the difference of texture, can ſuch different properties ariſe? That circumſtance therefore, deſerves attention. It has already been advanced, and clearly proved, that glaſs is a continuous ſubſtance void of pores, this property which it acquires by a perfect ſolution, is, without doubt, a neceſſary condition, and perhaps a principal cauſe in the production of tranſparency; for, in caſe of a mixture of diſſolvable bodies with water, the more perfect the ſolution, the greater will be the tranſparency of the liquid. Let ſalt, for inſtance, or any diſſolvable powder, be thrown into water, or ſome other diſſolvent, and then ſhaken together in a glaſs; the mixture will be opake, until the powder be perfectly diſſolved, or the undiſſolved parts, if any there be, fall to the bottom: for, as long as any undiſſolved parts remain ſuſpended, they will intercept the light, and the liquor will appear muddy and opake. But, when the ſolution is ſo perfect, and the two bodies ſo intimately blended, as to form, I may ſay, one homogeneous body, the tranſparency becomes compleat: wherefore, *vice verſa*, perfect tranſparency in a liquor thus impregnated, is the criterion of a true ſolution: conſequently, the tranſparency of glaſs is a proof that the flints, earth, ſtones, or whatever ſubſtances entered into its compoſition, were, according to Boerhaave's obſervations, by the power of alkali, and action of fire, perfectly diſſolved, as well as the alkali itſelf, which is made to flow like water.

This perfect ſolution, and uniform mixture of ſuch various matters, may ſeem inconſiſtent with the prevailing notion of the impenetrability of the primogenial particles of matter. But, in the firſt place, favourite ſyſtems, and hypothetical notions, however general, muſt always yield to poſitive facts. Again, we know that water, mercury, and every other fluid may be ſo penetrated, divided, and volatilized by heat, that the parts into which they are reſolved eſcape every organ of ſenſe. Beſides, we find by experience, that larger maſſes of matter, and the hardeſt of bodies, are by human contrivances, and material agents, reduced to parts imperceptibly ſmall; ſhould we not then conclude from analogy, that if theſe, or other cauſes of diviſion and diſſolution were continued, theſe very imperceptible parts might be further divided and reduced to others indefinitely ſmaller, and ſo on to a a minuteneſs beyond the limits of human conception?

The ſame thing is evident from experiment; for chymiſts find that the oil of vegetables, though ſo purified by repeated diſtillations, as to become tranſparent, ſtill contains a portion of earth, in ſo much that Boerhaave ſays, " Repeat the diſtillation ever " ſo often, there will be no end to the con- " verſion of oil into earth; ſo that the " greater part of the oil is converted into a " pure ſimple earth, for which ſee Boyle " on the mutability of principles." Now if oil, which is not only tranſparent itſelf, but renders paper more tranſparent than will any other fluid, contains ſo much earth, which is by nature opake, what a perfect ſolution muſt this earth undergo, when ſo attenuated as to become tranſparent?

The ſame author ſhews that a tranſparent *lixivium*, and a ſalt *per deliquium*, contain a pure earth, and concludes, that the earth diſcovered in thoſe fluids, really exiſted in them in ſo latent a form, that it ſuffered itſelf to be perfectly diſſolved. For the ſame reaſon pure earth, when thus latent in a tranſparent fluid or glaſs, is not only as minutely divided as a ſubtilized fluid, but alſo as perfectly diſſolved in the fluid or alkali, with which it is blended, as are the component parts of the fluid which diſſolves it. This thorough diffuſion, and intimate union of all the parts, is what we call a perfect ſolution, and, in every inſtance, appears neceſſary for tranſparency.

The example of the mixed metals has already exhibited the power of fire in penetrating and opening their moſt intimate parts, and in thoroughly blending them all in one homogeneous maſs, notwithſtanding the diſparity of their ſpecific gravities; conſequently, in the preſent inſtance, the diſſolved earth, and its ſolvent the alkali,-are, by the action of fire, ſo intimately diſſolved, and ſo effectually blended amongſt each other, when thus vitrified, as to leave no conceivable part or particle of this fluid vitrious maſs undiſſolved; in ſo much that we might, with ſome propriety, call it a ſolid flame. Nor can any man diveſted of prejudice, conceive a particle of earth that remains whole, and retains any original dimenſions, or that is not penetrated, in the firſt place by the alkali, but more effectually attenuated and diffuſed by the expanſive power of fire. Therefore, the whole maſs in its liquid ſtate, as well as in its cold and firm ſtate, is void of pores, and not made up of ſeparate particles, but a perfect *continuum* in ſubſtance and texture. And if, in this hot liquid ſtate, glaſs does not tranſmit light ſo copiouſly as when cold and firm, it is owing to an intimate tremour of its parts cauſed by heat; as may appear from water and other fluids, which are rendered leſs tranſparent by an agitation of their parts, occaſioned by heat or otherwiſe.

That ſuch a ſolution of the different ſpecies of matter, as removes every idea of pores, and produces a perfect continuity of ſubſtance, is attended with tranſparency, is clearly inſtanced in all tranſparent fluids; but the various changes of beer not only prove this aſſertion, but alſo its converſe, to wit, that a want of ſolution, and of continuity, is attended with opacity. At firſt this liquor is a pure tranſparent wort; afterwards, in the ſtate of fermentation with yeſt, it becomes muddy, and therefore opake; when perfectly ſolved and fined, it is again tranſparent: but, even then, if it were agitated and worked up in a glaſs to a porous frothy texture, it will once more become opake. In the firſt and third ſtate all its parts are in perfect ſolution, and therefore it is tranſparent; but not ſo in the ſecond and fourth; for the yeſt is not thoroughly blended with the liquor in the one, nor is the air intimately and evenly blended with it in the other.

How feeble and dim is the ſolar light in a fog, or during cloudy weather! But when the extraneous matters are in thorough ſolution with the air, the atmoſphere is perfectly tranſparent, and the ſolar beam appears bright and ſtrong. It cannot be pretended that the atmoſphere is more porous when clear than when miſty, and therefore better adapted to admit light; it ſhould rather be ſuppoſed more denſe when clear, as it is then heavieſt, for it ſupports in the barometer a greater column of mercury. The matter of the atmoſphere is the ſame in both caſes, and it is only the difference of texture that makes it perfectly tranſparent, or inclining to opacity. Chymiſts, apothecaries, and in general all who are converſant with making mixtures, could give an endleſs variety of thoſe examples; but one of the moſt convincing proofs poſſible, is the difference with regard to tranſparency between glaſs in its adheſive ſtate, and when broken and pounded to a powder; for, in this porous ſtate, it becomes quite opake, but again, when rendered a *continuum*, by being melted a ſecond time, its tranſparency is reſtored.

But as this continuity of bodies is apparently inimical to the tranſmiſſion of light, and quite ſubverſive of the preſent ſolution given of tranſparency, it is neceſſary to take into conſideration the grounds of the preſent opinion, and bring both the continuity of tranſparent bodies and the porous ſuppoſition to the teſt, by avowed principles and known facts. In this reſearch, we ſhall find a ſufficient number of facts to reaſon upon, already ſtated in Newton's Optics; ſo that our chief buſineſs will be to remark the juſt inferences thence to be drawn, and to guard againſt miſinterpretations.

Newton defines the *reflangibility* of rays of light, "*their diſpoſition to be turned out of their* "*way, in paſſing out of one tranſparent body in-* "*to another.*" *Reflexibility* he defines, "*their* "*diſpoſition to be turned back into the ſame me-* "*dium, from any other medium upon whoſe ſur-* "*face they fall.*" So that refraction, as it is the tranſmiſſion of light through bodies more or leſs obliquely, is analogous to tranſparency; and reflection, which is the turning back of light from the ſurface of a body, and not paſſing through it, is analogous to opacity. After various experiments and obſervations relating to light and colours, (which are not pertinent to our ſubject) this author comes at length to conſider the cauſe of the reflection of light, with regard to which, he advances this propoſition, (Optics

p. 237) "*The cauſe of reflection is not the im-*
"*pinging of light on the ſolid or impervious parts*
"*of bodies, as is commonly believed.*"

"This" (continues he) "will appear by "the following conſiderations. Firſt, That "in the paſſage of light out of glaſs into air, "there is a reflection as ſtrong as in its paſ-"ſage out of air into glaſs, or rather a little "ſtronger, and by many degrees ſtronger "than in its paſſage out of glaſs into water. "And it ſeems not probable that air ſhould "have more ſtrongly reflecting parts than "water or glaſs. But if that ſhould poſſibly "be ſuppoſed, yet it will avail nothing; for "the reflection is as ſtrong or ſtronger, when "the air is drawn away from the glaſs, (ſup-"poſe by the air pump.")

From this firſt illuſtration of his propoſition we may collect, that light, tranſmitted by glaſs, is more reflected on the other ſide by air than by water, and moſt of all by a *vacuum*. We agree with him, that it is not at all probable that air ſhould have more ſtrongly reflecting parts than water or glaſs: but as to the immediate cauſe of reflection we are not as yet determined, nor ſhall we ſay any thing about it, until that point becomes the object of our conſideration; for we find that theſe ſolid bodies reflect light, and, at the ſame time, that glaſs, though a ſolid, firm body, and water, which is a very denſe fluid, tranſmit light more copiouſly than a *vacuum*; we therefore only conclude, that denſity and firmneſs of matter are not ſuch impediments to the paſſage of light, as is commonly believed; for the denſity of water is eſteemed 800 or 1000 times greater than that of air, and is, we may ſay, infinitely greater than that of a pneumatic *vacuum*; yet the latter reflects light, and intercepts and reſiſts its paſſage more than glaſs or water, which, notwithſtanding their denſity, not only tranſmit, but apparently accelerate the motion of light.

"Secondly, If light in its paſſage out of "glaſs into air, be incident more obliquely "than at an angle of 40 or 41 degrees, it is "wholly reflected; if leſs obliquely, it is in "a great meaſure tranſmitted. Now it is "not to be imagined that light at one de- "gree of obliquity ſhould meet with pores "enough in the air to tranſmit the greater "part of it, and at another degree of ob-

" liquity ſhould meet with nothing but parts " to reflect it wholly; eſpecially, conſidering " that in its paſſage out of air into glaſs, " how oblique ſoever be its incidence, it " finds pores enough in the glaſs to tranſmit " a great part of it."

On this ſecond illuſtration, we obſerve with him, that it is certainly inconſiſtent to ſuppoſe, that light in one direction *ſhould meet with nothing in air but ſolid parts to reflect*: but again, it is equally inconſiſtent to ſuppoſe, that in another direction it ſhould meet with nothing but pores, by which it is tranſmitted; ſo that if the former inconſiſtency militates againſt the reflection of light by parts, the latter militates equally againſt its tranſmiſſion by pores, which is a ſuppoſition equally groundleſs with that which he objects to.

" Thirdly," (he ſays) " If the colours " made by a priſm placed at the entrance of " a beam of light into a darkened room, be " ſucceſſively caſt on a ſecond priſm, placed " at a greater diſtance from the former, in " ſuch manner that they are all alike inci- " dent upon it, the ſecond priſm may be ſo "inclined to the incident rays, that thoſe "which are of a blue colour ſhall be all re- "flected by it, and yet thoſe of a red colour "pretty copiouſly tranſmitted. Now if the "reflection be cauſed by the parts of air or "glaſs, I would aſk, why at one obliquity of "incidence the blue ſhould wholly impinge "on thoſe parts, ſo as to be all reflected, "and yet the red find pores enough to be in "a great meaſure tranſmitted?" This certainly is an unanſwerable argument againſt the reflection of light by particles; but it is equally forcible againſt the tranſmiſſion of light by pores: for, ſince the red particles of light are, according to Newton, the largeſt, we may with juſtice aſk, if the pores of tranſparent bodies are ſuppoſed to be the only paſſage for light, how the largeſt particles gain a paſſage through pores that will not admit the ſmaller, for the blue do not paſs, but are reflected? And ſince we learn, from his experiments, that a vacuum reflects more than ſolid bodies, ſhould we not ſtill conclude, that the ſolid parts admit the tranſmiſſion of light more than pores?

But this point may receive ſtill greater illuſtration from ſome facts ſtated in the confirmation of his firſt propoſition. He tells us then from obſervation, (p. 221) " that in " the confine of air and glaſs, the reflection " is ſtronger than in the confine of glaſs and " water. If water be diſtinguiſhed by any " imaginary ſurface, the reflection in the " confine of theſe two parts is none at all.— " In the confine of two glaſſes of equal den- " ſity, there is not any ſenſible reflection." Whence he concludes, " ſo then the reaſon " why uniform pellucid mediums, (ſuch as " water, glaſs, or chryſtal) have no ſenſible " reflection but in their external ſuperficies, " where they are adjacent to other mediums " of a different denſity, is, becauſe all their " contiguous parts have one and and the " ſame degree of denſity." Here we have a former obſervation verified, to wit, that the denſer mediums are beſt adapted to tranſmit light, and reflect it leaſt. Moreover, we find that there is no reflection, but a total tranſmiſſion, *when all the contiguous parts have one and the ſame degree of denſity*. But, when all contiguous parts of a medium have one and the ſame degree of denſity, is it not ſomething like a *continuum* of ſubſtance?

This is confirmed by his ſecond propoſition, to wit, "*The leaſt parts of all natural bo-* "*dies are in ſome meaſure tranſparent: and the* "*opacity of thoſe bodies ariſeth from the multitude* "*of reflections cauſed in their internal parts,*" *i. e.* by the pores that ſubſiſt in their internal parts; for, by the laſt propoſition, if theſe parts were immediately contiguous, being of the ſame denſity, there would be no reflection; therefore the multitude of reflections proceed from the multitude of void ſpaces between thoſe parts, that is, the multitude of pores: conſequently, opacity, which ariſeth from thoſe reflections, is occaſioned by pores.

Again, thoſe *leaſt parts of natural bodies* muſt be ſuppoſed to be the *primary particles of matter*, which the ſame author holds to be *ſolid* and *impenetrable*, therefore void of pores. Thus we ſee tranſparency attend continuity, as we have juſt ſeen opacity produced by pores. From the preceding obſervations, Newton then collects his third propoſition, which is as follows, "*Between the parts of* "*opake and coloured bodies are many ſpaces,* "*either empty, or repleniſhed with mediums of* "*other denſities.*" This propoſition is an immediate conſequence of the laſt; for having proved before that opacity ariſes from pores, it is juſt to conclude, from the opacity of many bodies, that they are porous, or have empty ſpaces between their parts. However, as the illuſtration the author gives of it confirms all the preceding obſervations, and throws great light upon the preſent queſtion, we ſhall inſert it, notwithſtanding the length of the quotation.

"The truth of this" (the above propoſition) "is evinced by the two precedent propoſitions: for, by the ſecond propoſition, "there are many reflections made by the internal parts of bodies, which, by the firſt "propoſition would not happen, if the parts "of thoſe bodies were continued without "any ſuch interſtices between them; be"cauſe reflections are cauſed only in ſuperficies which intercede mediums of a dif"ferent denſity, by propoſition the firſt.

"But farther, that this diſcontinuity of "parts is the principal cauſe of the opa"city of bodies, will appear, by conſider"ing, that opake ſubſtances become tranſpa"rent by filling their pores with any ſub-

" ſtance of equal, or almoſt equal denſity " with their parts. Thus paper dipped in " water or oil, the *oculus mundi* ſtone ſteeped " in water, linen cloth oiled or varniſhed, " and many other ſubſtances ſoaked in ſuch " liquors as will pervade their little pores, " become by that means more tranſparent " than otherwiſe. So, on the contrary, the " moſt tranſparent ſubſtances may, by eva- " cuating their pores, or ſeparating their " parts, be rendered ſufficiently opake; as " ſalts, or wet paper, or the *oculus mundi* " ſtone by being dried, horn by being ſcrap- " ed, glaſs by being reduced to powder, or " otherwiſe flawed, turpentine by being ſtir- " red about with water, till they mix imper- " fectly, and water by being formed into " many ſmall bubbles, either alone in the " form of froth, or by ſhaking it together " with oil of turpentine, or oil of olive, or " ſome other convenient liquor with which " it will not incorporate. And to the in- " creaſe of the opacity of all theſe bodies, it " conduces ſomething, that, by the twenty- " third obſervation, the reflection of very " thin tranſparent ſubſtances, are conſidera- " bly ſtronger than thoſe made by the ſame " ſubſtances of a greater thickneſs."

After ſuch numerous experiments, and ſuch forcible arguments to prove that the ſolid matter of tranſparent bodies induces the refraction and tranſmiſſion of light, as much as vacuities or a want of matter does reflection and opacity; who would expect to hear the ſame author in the next page aſſert, that "*water, glaſs, ſalt,* &c. *upon divers conſiderations*," (which he does not mention) "*ſeem to be as full of pores or interſtices between their parts as other bodies are; but yet their parts and interſtices to be too ſmall to cauſe reflection in their common ſurfaces?*" All the grounds we can find in his works for this opinion, except mere hypotheſis, are as follows; and perhaps the reaſons he adduces, when duly examined, will not appear more ſatisfactory than the hypotheſis is grounded.

* "And hence we may underſtand, that "bodies are much more rare and porous "than is commonly believed. Water is "nineteen times lighter, and, by conſe"quence, nineteen times rarer than gold; "and gold is ſo rare, as very readily, and "without the leaſt oppoſition, to tranſmit

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* See Optics, page 242.

" the magnetic effluvia, and eaſily to admit
" quickſilver into its pores, and to let water
" paſs through it. For a concave ſphere of
" gold, filled with water, and ſoldered up,
" has, upon preſſing the ſphere with great
" force, let the water ſqueeze throught it,
" and ſtand all over its outſide, in multi-
" tudes of ſmall drops like dew, without
" burſting or cracking the body of the gold;
" from all which we may conclude, that gold
" has more pores than ſolid parts, and, by
" conſequence, that water has above forty
" times more pores than parts: and he that
" ſhall find out an hypotheſis by which wa-
" ter may be ſo rare, and yet not be capable
" of compreſſion by force, may doubtleſs,
" by the ſame hypotheſis, make gold and
" water, and all other bodies as much rarer
" as he pleaſes, ſo that light may find a
" ready paſſage through tranſparent ſub-
" ſtances."

This ſingular paragraph deſerves the cloſeſt attention. To ſay that water ſhould be nineteen times more porous than the gold, which in the experiment he mentions it ſqueezes through, is perfectly inconſiſtent; for gold, by hammering or compreſſion, may be reduced to a ſmaller volume, and is pervaded by water, which are evident proofs of its poroſity. But water, from this experiment, is ſaid to be incompreſſible by any force, which is a proof that it contains no pores or empty ſpaces; for it is allowed to be a fluid whoſe parts are eaſily moved amongſt each other, and yield to every force; if then it contained pores or vacuities, it could not be incompreſſible, becauſe the ſolid parts, being violently preſſed, would enter into thoſe vacuities, which would contract its dimenſions, and leſſen its volume. However it retains its dimenſions under that preſſure, and rather than leſſen its volume, will force a paſſage through gold. Does not this ſhew, not only that gold is more porous than it, but alſo that it is void of pores, that is, a *continuum* of ſubſtance; on which account, according to our reaſonings on Newton's own experiments and obſervations, it ſhould be tranſparent?

Neither do we ſee how he is authorized to conclude from the experiment, that gold has more pores than ſolid parts; for the paſſages which water has to run through a ſieve are leſs than the ſolid parts, and yet the fluid paſſes freely; on the contrary, the great force neceſſary to make the water ſqueeze through gold, ſhould be a proof that the pores of gold are far leſs than the ſolid parts; which may alſo be collected from its extreme ductility. But what is moſt ſtrange is, that this great man, who eſtabliſhes a rule againſt hypotheſes when oppoſed to arguments founded on induction, ſhould admit of an hypotheſis for the tranſmiſſion of light by pores through pellucid bodies, after ſo many experiments and arguments ſhewing pores to be a cauſe of reflection, and therefore an impediment to the tranſmiſſion of light, and even acknowledged by himſelf to be the cauſe of opacity. To ſay that man ſhould by any hypotheſis make water, or any other body more porous than it really is, without ſome actual operation to change its context, is perfectly unphyſical. Indeed any liquid may be rendered very porous, by being raiſed to a froth; but it muſt be remarked, that they are thereby rendered opake; other bodies alſo may be rendered leſs porous, as paper by being moiſtened, or metals by being hammered, but this change diminiſhes their opacity, as appears by gold leaf.

Nevertheleſs, Newton not only gives any man leave to make all bodies as porous as he pleaſes, but is himſelf the firſt to make uſe of this extraordinary privilege. His hypotheſis is thus (Optics p. 243) " If we conceive the " particles of bodies to be ſo diſpoſed amongſt " themſelves, that the intervals or empty " ſpaces between them may be equal in mag-" nitude to them all; and that theſe par-" ticles may be compoſed of other particles " much ſmaller, which have as much empty " ſpace between them, as equals all the mag-" nitudes of thoſe ſmaller particles: and that " in like manner theſe ſmaller particles are " again compoſed of others much ſmaller," &c. " and ſo on perpetually till you come " to ſolid particles, ſuch as have no pores or " empty ſpaces within them," &c.

However ideal and arbitrary this hypotheſis be, it might be overlooked as a looſe thought of that great man, if it was not revered by his followers, and propoſed to the world as a real and philoſophical foundation for a tenet, which our ſenſes contradict, and our reaſon diſavows; I mean the porouſneſs of glaſs. By this ingenious hypotheſis a ſchoolboy, who knows arithmetic enough to extend a ſeries, may ſport with the works of Omnipotence, and Dr. Keil, and Mr Martin will put all the matter of the univerſe into a lady's thimble;* nay theſe authors, on like grounds, might have gone farther, and made it all fit in the eye of a cambrick needle; for Democritus declares, that no man ever ſaw or can ſee the atoms of matter. We have only then to form an hypotheſis, and ſuppoſe them to be mathematical points; and then, as all ſuch points that can be conceived by the mind of man make no more than a mathematical point, therefore all the atoms in the univerſe, will make but one, and readily enter into the eye of a needle.

Beſides this abſurdity, the dividing and ſubdividing particles at pleaſure, is quite contrary to the Newtonian principles; for the primary particles of body, though tranſparent, are impenetrable and poreleſs; they are alſo of a determined magnitude, according to the ſame philoſophy, and therefore cannot be reduced to every degree of exiguity, which the imagination of a mathematician may ſuggeſt. This we may infer from Mr. Martin, (vol. 1, p. 8) where he tells us that "figurability is as neceſſary to "matter, as ſolidity or extenſion. On this "property ſeveral things of moment de-"pend. Thus, according to the ſeveral "figures of the corpuſcles, they will touch "by a greater or leſſer quantity of ſurface, "and ſo will cohere more or leſs firmly to-"gether; from hence will ariſe various qua-"lities of bodies, which are the foundation "of moſt of the conſiderable phænomena of "nature." But that the particles of matter are not ſuppoſed to be *infiniteſſimals*, nor ſubject to this arbitrary reduction, appears more clearly from Newton's own opinions. For although the particles of light be always ſuppoſed ſmaller than the corpuſcles of any other matter, he pronounces the rays of light to be "ſmall bodies of different magnitudes," and is of opinion (Opt. 29th query) "that the un-"uſual refraction of iſland chryſtal is perform-"ed by ſome attractive virtue lodged in *certain* "*ſides* both of the rays, and of the particles "of the chryſtal.—I do not ſay this virtue is "magnetical, it ſeems to be of another kind; "I only ſay, that whatever it be, it is dif-"ficult to conceive that the rays of light, un-

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* See ſecond Volume of Philoſophia Britanicæ on Light, page 294.

"leſs they be *bodies*" (we might ſay of a ſenſible magnitude) "can have a permanent "virtue in two of their ſides, which is not "in their other ſides, and this without any "regard to their poſition, or to the ſpace or "medium through which they paſs." Again, according to the ſame author, matter is formed of "*ſolid*, *maſſy*, *hard*, *impenetrable* "particles, incomparably harder than any "*porous* bodies compoſed of them, even ſo "very hard as never to *break or wear in* "*pieces*," conſequently, they are neither porous, nor reſolvable into ſmaller particles, though of ſuch a ſize as to have different virtues on different ſides, and to be of ſuch importance, as by their different figures to produce moſt of the conſiderable phænomena of nature. If ſo, how can this porous hypotheſis be admitted? Beſides, theſe particles not being reſolvable into others ſmaller than themſelves, are certainly the leaſt parts of natural bodies; but *the leaſt parts of almoſt all natural bodies*, by the ſecond propoſition of Newton's ſecond book of Optics, are tranſparent; if then, poreleſs particles may be thus tranſparent, where is the neceſſity for a porous hypotheſis?

From theſe conſiderations, and the other obſervations and arguments ſtated throughout this ſection, it appears, that the doctrine of light's tranſmiſſion by pores, is intirely ſuppoſititious, and inadequate to explain the phænomena; it may alſo be collected, that the hypotheſis of pores in tranſparent bodies, is equally groundleſs. But to be fully ſatisfied with regard to theſe two points, we have only to ſuſpend a ſolid globe of pure glaſs in the ſun-beam, or day-light. Turn this globe from ſide to ſide, it will tranſmit the light in every poſition; now Newton tells us (Optics, p. 243) that "the rays of "light, whether they be very ſmall bodies "projected, or only *motion* or *force* propa"gated, are moved in right lines; and "whenever a ray of light is by any obſtacle "turned out of its rectilinear way, it will "never return into the ſame rectilinear way, "unleſs perhaps by very great accident." If then light was tranſmitted by pores, there ſhould be lines of pores through this glaſs in every poſſible direction, without the interpoſition of any ſolid particles; for, according to this opinion, if the lines of pores were in any direction interrupted by ſolid parts, the rays of light could not be tranſted by them, nor could the ſphere be tranſparent in that direction. Now is it conformable to reaſon to ſuppoſe, that without any contrivance to form or regulate its pores, this ſolid maſs is *perfectly* and rectilineally perforated, not in one direction only, nor in ten, but in every direction and poſition that poſſibly can be given to it? And if this total perforation was admitted in a ſubſtance, in which no experiment has ever realized a pore, would it not follow that the globe of glaſs is in every part an empty ſpace, a perfect void?

Another obvious method of bringing this point to the teſt, is by a convex lens. With this glaſs, any object or number of objects, even all thoſe of a landſcape, may be perfectly delineated in a camera obſcura. And a picture thence taken being placed in an optical inſtrument, and viewed through the convex lens, will preſent a moſt accurate and natural repreſentation of the objects ſo depicted. Now if the light radiating from thoſe objects, only found a paſſage through the pores of the lens, this perfect repreſentation would be impoſſible; becauſe lines of pores could not be ſuppoſed ſo exactly placed before all the points of ſeveral objects with ſuch paralleliſm and inclination, as ſhould anſwer to all the directions of the pervading rays of light, ſo that all theſe objects ſhould be juſtly and perfectly depicted. For if the light coming from any point or part of the object was either intercepted or miſguided to improper places in the picture, the repreſentation would be diſtorted, deformed, and conſequently moſt imperfect. But we find by experiment, that all well-formed and well-poliſhed lenſes, render in their *foci* perfect images of the objects they are preſented to, except there happen to be in the glaſs a crack, a ſpeck, or a flaw, which are always found to ſtop, miſguide, or refract the light, ſo as to render the image diſtorted and imperfect. Conſequently, if there were a great number of cracks or ſpecks in the lens, the image ſhould be monſtrouſly deformed and obſcured. Now the cracks repreſent pores, and the ſpecks ariſe from undiſſolved, and conſequently porous parts; have we not therefore, by this caricature of the object, an experimental proof of what the conſequence ſhould be, were the glaſs made up of pores and particles?

SECTION III.

Denſity favourable to the Communication of Heat; the ſame Thing obſerved of Light. Qualities require Subſtances. The Luminous Subſtance in tranſparent Bodies, revived to the Quality of the Light they are immerſed in.

HAVING in the two preceding Sections gathered from the nature of light, from the texture of tranſparent bodies, and from the phænomena of tranſparency, the inconſiſtency of the preſent ſolution of that property, and having weakened thoſe prejudices, which might bias or miſguide us in the purſuit of truth, we are now qualified to enter upon a direct inveſtigation of that *deſideratum*. For this purpoſe, it occurs that the communication of heat might be an uſeful conſideration; for we have always obſerved throughout this work, that heat and light are properties of the ſame ſubſtance, and generally concomitants; moreover, according to our philoſophical theory, qualities cannot ſubſiſt without their ſupporting ſubſtances. In whatever manner then the ſubſtance of fire or light acts, in order to communicate heat through bodies, it is probable the ſame 'ſubſtance may, by ſimilar means, effect the communication of light: for nature is ſimple in all her operations, and a material ſubſtance, though it may produce various effects, has but one propenſity and mode of operation.

If a bar of any kind of metal be ſet upright with one end in the fire, the heat will ſoon be propagated through the ſubſtance of the ſolid metal to the other end, and will there become far more ſenſible than in the adjacent air, even ſo ſenſible, as to burn a perſon who ſhould apply his hand to it. Again, if another piece of metal be held in contact with this hot bar, it will partake of its heat; whereas, if it be held at a ſmall diſtance from it, ſuppoſe an inch, it will not be ſenſibly heated, no more than the air that occupies the intermediate ſpace; but if a more denſe medium, as water, intervene, ſo as to touch both, it ſhall in time, not only conceive heat itſelf from the hot bar, but ſhall communicate heat to the ſecond, ſo as to become a conductor between both. Thus we ſee, that denſe and ſolid bodies are more accumulative and tenacious of heat, than rarer bodies, and that rare mediums, and vacant ſpaces, intercept heat, and do not conceive it, but might ſeem to reflect it, while denſe bodies conduct and communicate it; whence it may be inferred, that the tranſpoſition of heat is not effected by a tranſition of the burning matter, or a penetration of it through the bar, for ſuch penetration would be the more eaſy, according as the ſubſtance was rare, but by a propagation of the quality through its own proper ſubſtance, when excited.

To give an inſtance more ſtriking and familiar, if a large metal pot be ſet empty on the fire, in ſome time the ſides and bottom will become too hot for the hand to endure, while the air it contains will not conceive more than a ſenſible heat. But if it be filled with water, that more denſe fluid will in ſome time acquire an heat not inferior to that of the metal, and be capable of communicating it to any other denſe body, partly immerſed in the water. This agrees with what we have juſt obſerved, and with Sir Iſaac Newton's remarks on the tranſmiſſion of light, to wit, "*that in the paſſage of light out of glaſs* "*into air, there is a reflection as ſtrong or* "*ſtronger than in its paſſage out of air into glaſs,* "*and by many degrees ſtronger than in its paſ-*"*ſage out of glaſs into water, and that the re-*"*flection is ſtronger*" (out of glaſs into a vacuum,) "*when the air is drawn away by the* "*air-pump.*" Thus we ſee that a very rare medium, as air, has the ſame effect on both heat and light. It does not admit, but ſtops, intercepts, and ſeems to reflect both, for all which, a vacuum is ſtill more remarkable. Newton, in his propoſitions, imputes this to a power of reflection in the rare medium; yet ſome of his followers ſay it is by an attraction of the denſer body, which prevents the light from paſſing through; and may they not ſay the ſame thing of heat? I would rather ſay, conformably to the phyſical principles laid down, that as qualities require ſupporting ſubſtances, without which they cannot ſubſiſt, heat and light cannot ſubſiſt except in their ſupporting ſubſtances; ſo where this is deficient they will be weak, and where this is abſent, they will not exiſt. This concluſion is the more reaſonable in a ſyſtem into which imaginary powers are not to be admitted. The idea of reflection correſponds with that of reſiſtance, which is the effect of body or matter, wherefore it is impoſſible that reflection ſhould be greateſt, where body or matter is leaſt; therefore a vacuum can neither reflect heat or light, nor ſhould it however tranſmit or communicate them, for want of a vehicle, *i. e.* the ſupporting ſubſtance on which theſe qualities depend; whence it appears that porous bodies ſhould not be ſo adapted for heat or tranſparency, as thoſe that are denſe.

As to attraction, we ſhould not reſt much upon it in the explanation of a phænomenon, until we are better acquainted with its cauſe; but admitting it, according to the idea we can form of it, to be in every body, it ſeems that it ſhould not ſuffer to paſs through or recede from a body any thing, which it was capable of drawing into it: now light ſeems to paſs through and recede from the moſt denſe of all diaphanous bodies, as diamond and glaſs. Beſides, the attractive power of a body ſhould be the ſame, or nearly ſo, in all poſitions; however, if light in its paſſage out of glaſs into air, be incident more obliquely than at an angle of 40 or 41 degrees, it is wholly reflected; if leſs obliquely, it is in a great meaſure tranſmitted. And Newton throughout theſe experiments, rather chooſes to ſay, the rarer medium reflects, than that the more denſe attracts: but the true interpretation ſeems to be, that the moſt denſe bodies, containing proper matter to conceive and ſuſtain heat and light, are the beſt conductors for both.

This is again confirmed by his firſt obſervation, (ſecond book of his Optics) "Compreſſing two priſms hard together, that "their ſides, (which by chance were a little "convex) might ſomewhere touch one another, I found the place in which they touched, to become abſolutely tranſparent, as "if they had there been one continued piece "of glaſs. For when light fell ſo obliquely "on the air, which in the other places was "between them, as to be *reflected*, it ſeemed "in that place of contact, to be wholly tranſmitted, in ſo much, that when looked upon, it appeared like a dark or black ſpot, "by reaſon that little or no ſenſible light was "reflected from thence; and through this "ſpot, objects that were beyond might be "ſeen diſtinctly, which could not at all be "ſeen through other parts of the glaſſes, "when the air was interjacent." Thus we find again, that where denſe bodies touch, the quality of light, as well as that of heat, is tranſmitted and propagated from one to the other, but that it is intercepted when a vacuum, or a very rare medium as air intervenes: conſequently, ſince denſe matter is beſt qualified for propagating and tranſmitting theſe two qualities of the ſun, and a vacuum is wholly unqualified for the propagation of either, we might almoſt pronounce from experiment, that the ſpace between the ſun and planets is not a vacuum.

We have in the fourth Lecture reſolved body by the power of fire into its elementary parts, to wit, ſalt, virgin earth or inert matter, and light, which laſt is the chief component of the elaſtic matter, or baſis of air, and makes up a conſiderable part in the compoſition of bodies. Theſe elementary matters enter into the compoſition of all kinds of body, whether vegetable, animal, or foſſil; whence we have ſhewn, that they are the accretions of all bodies, and the ſource of their growth, weight, and magnitude; wherefore not only earth and air, but light alſo becomes a concrete in the moſt minute *rudiments and intimate ſtamina* of every body. The powers and qualities found in bodies depend on the nature and quantity of their peculiar principle, and the quantity or ſtrength of the powers in any body, peculiar to a certain principle, muſt be in proportion to the quantity, which the body contains, of the ſubſtance of that principle: thus when levity, vivacity, and expanſive vigour predominate in a body, whether ſolid or fluid, the expanſive principle or baſis of light and heat muſt be the chief ingredient of that body, as, for inſtance, in ſpirits and unctuous matters. On the other hand, where denſity, coheſion, and weight predominate, the coercive matter muſt be a chief part in the compoſition of the body, for example, in metals, ſtones, ſalts, &c. whoſe fires are thereby firmly compacted: and where neither predominate to a degree proportioned to the magnitude of the body, there the inert matter muſt abound. Thus indications are obtained of the chief principles of each body, that is in approach to either extreme, or in other intermediate proportions between them, and alſo where theſe principles are more equally incorporated; ſo that by thus penetrating into the principles of body, we may determine, not only the real eſſences of the elementary matters, but even of compound bodies, whoſe nominal eſſence only has been hitherto conſidered, the real having been ſuppoſed unattainable.

The truth of the above theory is continually experienced in chymiſtry, pharmacy, dying, and in all the arts of compounding and decompounding matters. But it is particularly exemplified in the uſe of touching-needles, whereby the proportion of different metals in a compound, is determined by the proportion of the ſame metals in the needle, with which it is found to agree on the touch-ſtone. Vintners likewiſe, and perſons well acquainted with the taſtes of different wines ſometimes arrive to ſuch a degree of ſkill, as to be able to aſcertain the quantity and kinds of natural wines, whereof an artificial wine is made up; but it is not to be expected that a perſon who is not an accurate judge of the ſimples in this, or any other branch, will be capable of ſuch diſcernment.

But we ſhall now aſſume an inſtance more generally known and deciſive, to wit, a beverage compoſed of water, ſpirit, ſugar, and acid, commonly called *punch*. This liquor is generally made in the preſence of judges, who before it is drank, examine it maturely by three ſenſible organs, to wit, thoſe of ſeeing, ſmelling, and taſting, of which the laſt is the chief teſt. Each gives his opinion candidly, without deceit or reſtraint; if it be found too acid, all agree that it has got the lemon juice in too high a proportion for the other ingredients, of which therefore a proper quantity muſt be ſupplied; if, on the other hand, it be found too ſweet, they agree that too much ſugar was put in; if too ſtrong or too weak, they agree that the ſpirit or water has exceeded the juſt proportion, and the other ingredients are ſupplied accordingly in proper quantities, until the liquor be brought to the true ſtandard. Now ſince nothing is examined more freely and impartially, there cannot be a more fair experimental proof of the truth of our theory, to wit, that each power or eſſence has its ſupporting ſubſtance, and that the power or quality depending on the real eſſence, is in proportion to the quantity of its peculiar ſubſtance. It is evident that theſe qualities blend with each other, as do their ſupporting ſubſtances, and that if in this liquor there was a ſenſible interſtice, or ſpace without any ſubſtance, that ſpace ſhould alſo be void of qualities, through a want of a ſupporting ſubſtance.

Now ſince all bodies are impregnated with the ſubſtance of fire or light, and ſince the luminous ſpecies is irritable by heat, and excited by action to operate according to its eſſenſe, *viz.* to expand and enlarge its dimenſions; therefore every part or particle of matter, wherein it is a concrete, ſhould alſo expand or be enlarged by heat. And hence the dimenſions of all bodies whether firm or fluid are enlarged by heat: by the continuance of heat, the ſmalleſt and moſt intimate parts of the firmeſt metals are diſſolved, and thoſe of different metals intimately blended. Hence flint, ſteel, and other hard bodies, emit fire by colliſion; and from an irritation of their conſtituent fires, firm bodies become hot by friction, metals by hammering, &c. From this fiery concrete in body alſo, the heat acquired by a bar of metal at one end is communicated to the other by its own proper ſpecies, without any change of place in any one part or particle thereof, or any tranſpoſition of the fiery matter that excites it. It is the ſame concrete in wood and fuel, when excited and fanned with air, that burns ſuch inflammable bodies to a coal, and that begets the ſcintillating ſparks, which run through the black coal of paper and thin bodies, as it were, to devour their intimate *ſtamina*, whereby every ſuch body is ultimately diſſolved, and its elementary matters are ſeparated and detached, except the inert matter and concrete ſalt, which ſtill remain blended together.

Hence, as Boerhaave remarks, there is not a body or place in nature void of this fiery ſpecies, whoſe eſſence and inſeparable property is expanſion; for doubtleſs it muſt be in all bodies which abſorb the ſolar light, and in all ſpace through which he effuſes his ſpecies; but in as much as it becomes a concrete in every body, we cannot admit with him that it is extraneous thereto, and only "*lodged* "*in vacuo, or in their pores, as in veſſels where it* "*is frequently agitated, and always in action.*"

Now as eſſences are as their ſubſtances, and the powers and qualities of a compound body are as the natures and quantities of its elementary ſubſtances, it follows, that as bodies incorporate more or leſs of the ſolar ſpecies, in reſpect to their other matters, they are more or leſs volatile and inflammable, or more or leſs rare, which, of courſe, occaſions a diminution of their ſpecific gravity.

Again, if the adheſive matter be the ſource of gravity in body, it ſhall alſo follow, that as a body contains more or leſs of this concentrating matter, in reſpect to its other *elementaries*, it ſhall be more or leſs firm, tenacious, and more or leſs heavy; and, of conſequence, metals which are the heavieſt and firmeſt of all bodies, will contain this concentrating matter in a greater proportion to their other matters, than any other kind of bodies, and next to metals, ſtones. Hence the fiery ſpecies of metals is ſo firmly bound down in their context, as to require a great degree of heat to liquify and fuſe them. This fuſion is effected by the innate expanſion of the fiery ſpecies, inherent in the moſt intimate particles of their ſubſtance; wherefore a prodigious degree of heat is neceſſary to give this ſpecies ſufficient vigour and expanſion to conquer their coheſion in ſuch a manner, as to cauſe an ebullition of their parts. For, on account of this adheſive principle, the more denſe and heavy a body is, and the more any fluid is preſſed, the more heat is neceſſary to make it boil. Thus the more heavy the atmoſphere, the more heat is neceſſary to make water boil; this is diſcovered by means of the thermometer; on the other hand, the lighter the atmoſphere, the leſs heat is neceſſary, ſo that a ſmall degree of heat makes water boil under an exhauſted receiver. However, other liquids, though not ſo heavy, may, from a greater degree of tenacity, require a greater degree of heat to cauſe an ebullition. Thus oils require a greater heat than water, to make them boil. It is alſo the great quantity of the ſaline or concentrating principle, which enters into the compoſition of glaſs, that binds down the fiery principle in it ſo effectually, as to be capable of a moſt intenſe heat, and of tranſparency, when qualified for that property by a continuity of ſubſtance.

From the nature of this concentrating matter, and the quantities of it bodies contain, the experiments mentioned are obviouſly explained; for heat in bodies being an irritation of their own native fires, it follows, that the denſer the matters, the ſtronger ſhould be the heat, the nearer the touching bodies are to an equality of denſity, the more equal the propagation of heat through them, and the more different they are in denſity, the more unequal the propagation of heat and the more interrupted its tranſmiſſion; a rare medium always interrupting its progreſs, and a vacuum entirely ſtopping it, ſo as to ſeem to reflect it or react againſt it: for, being void of ſubſtance, it ſhould be void of heat, light, and of all other qualities; whereas the reverſe ſhould happen, if heat paſſed through bodies, as light is commonly ſuppoſed to do.

All this has the ſtricteſt conformity with what Newton hath collected from his experiments on the tranſmiſſion of light by tranſparent bodies; this tranſmiſſion was interrupted by the rare medium of air, ſtopt by a vacuum, and aſſiſted by water; but ſuffered no interruption when the ſame kind of diaphanous bodies were in contact, no more than if they were the continued ſubſtance of one and the ſame body of that ſpecies. He found that in tranſparent bodies, the denſer they are, the more they refract light, and the ſwifter they tranſmit it; whereas the more rare [illegible] *i. e.* tranſmit it leaſt; and that a vacuum cauſes total reflection, *i. e.* tranſmits little or none at all. As a farther reſemblance, it hath been obſerved, that the refractions or tranſmiſſions of light were more alike, where the touching bodies were neareſt to equality in denſity; and where the denſities differed moſt, ſo did the powers of refracting; that in denſer mediums refraction increaſed to a perfect tranſparency, or total tranſmiſſion; whereas the reflective power increaſed with the rarity of the medium, ſo that tranſparent mediums being rendered porous, become opake. (See the illuſtrations of his 1ſt, 3d, and 8th Propoſitions, B. II. Opt.) From all this we have already concluded, that opacity of body attends its poroſity, and tranſparency its continuity. At preſent we have likewiſe room to conclude, that the intenſity and propagation of heat attends the compactneſs of matter, and that a defect and interruption thereof, are the conſequence of pores; whence we ſee that theſe concomitants of the ſolar effuſions, to wit, heat and light, are alike affected by the fabrication and context of body. Where bodies are moſt denſe and continuous, both are moſt powerful in their reſpective operations; but when bodies are rare, theſe qualities are weak. For they are both interrupted by pores and vacuities, which perhaps affect them alike.

And indeed nothing is more conſonant to the nature of things, than that the qualities of the ſame ſubſtance ſhould in like circumſtances be alike affected; for neither can ſubſiſt or act without its ſubſtance; conſequently, where there is a vacuum, or a ſpace void of this ſubſtance, it ſhould be void of its qualities; but where this ſubſtance exiſts, there its qualities ſhould alſo ſubſiſt, provided their cauſe of excitation (whatever that be) act on the ſubſtance. Since, then, the ſubſtance of light is contextured with the other component matters of bodies, and, as we have ſeen, intimately blended in the moſt minute *ſtamina* thereof, its qualities, when duly circumſtanced to excite ſenſation, will be moſt forcible in the moſt compact bodies, where this ſubſtance is moſt condenſed, and leſs powerful in rarer bodies, where this ſubſtance is not ſo compact. But in vacuo theſe qualities ſhould not ſubſiſt at all, except indeed in vacant ſpaces, which are very ſmall, as the pores of bodies; for the ſpecies iſſuing from the ſurrounding ſolids, or partitions may then ſupport theſe qualities in the interſtices; as we ſee the inflammable matter, or fiery ſpecies iſſuing from coals or other fuel on a fire cauſe heat and light in their pores and the intervals between them.

However as we diſcover in theſe ſpaces and in bodies, ſometimes heat without light, alſo light without heat, and are certain that the ſubſtance of fire is a concrete in every body, though it ſhould not exhibit either: it follows, that either the excitation or ſenſibility of theſe ſiſter-qualities depends alſo on other circumſtances not hitherto obſerved, wherein there may be a ſimilarity, but wherein alſo there may be a characteriſtical peculiarity; thus, for inſtance, we have already diſcovered a ſimilarity between them, in as much as denſity contributes to the vigour of both; and we have alſo perceived a peculiarity in the neceſſity of a continuous texture for the propagation of light, which is not found ſo neceſſary for the communication of heat. But it muſt be obſerved, that it is only the circumſtances which regard light that are here the object of inveſtigation.

We have already ſeen the inconſiſtency of attributing a projectile motion to light, and our obſervations on that ſubject have opened to us the real mode of its propagation from the ſun. As to its tranſmiſſion through diaphanous bodies, we have an abſolute certainty that it is not effected by a real tranſition of the luminous ſpecies through their pores; it is alſo certain, that light does not find a paſſage through the ſolid matter of thoſe bodies, *that* being inconſiſtent with the nature of matter: and further ſeeing that bodies which incorporate moſt of the ſubſtance of light, *cæteris paribus*, tranſmit it beſt; we muſt upon the whole conclude, that there is not any pervaſion at all of the matter of light through ſuch bodies; but that the light, which they exhibit, and which occaſions the phænomena of tranſparency, muſt be *that* contextured throughout their conſtitution in the form of elaſtic matter. This ſubſtance, though a concrete in all bodies, is latent, until revived by the lively action of light or flame, whoſe luminous effuſions quicken its own quality in this matter of its own nature contextured in a body, when ſurrounded by, or immerſed in light; juſt as we find that the quality of heat is revived in the fiery matter, which lies dormant in the compoſition of iron or other bodies, when theſe bodies are immerſed in, or acted upon by a living fire.

But to comprehend this, we muſt again take notice that the body of light, which fills the ſolar ſphere of illumination flowing from him *in orbem*, is a continuum preſent in all parts of that ſpace, except where intercepted by an opake body; and that an eye in any part of that expanſe to the bounds of light ſhall ſee the ſun the very inſtant it is turned thereto; becauſe the ſolar beam, *i. e.* the beam that ſtands between the eye and the ſun, being a continuum in ſubſtance and in contact with both, muſt affect the one, while it is urged by the other, though it were of a length indefinite, until ſenſation is loſt in one, or action in the other; ſo that, while the ſun retains its vigour, it ſhall be preſent to every ſenſible eye that is turned to it. Conſequently that beam or ray of light muſt ever be the inſtantaneous agent of viſion, while the continuity and tenſion of its matter are preſerved, and an unyielding contact of its ſpecies is continued. Now this unyielding contact is held up by the matter of glaſs and of other diaphanous bodies, whoſe chief concrete is the matter of light, therein compacted in the ſtate of a poreleſs contexture and homogeneous continuity. The latent quality of this luminous ſubſtance is revived and excited by the action, which the ambient light receives from the ſolar effuſions; juſt as heat is excited in a body by fire, or ambient heat, without any acceſſion or pervaſion of the fiery matter that acts upon the heated body; and as a body acted upon by a violent heat, which excites in all parts its innate fires, appears itſelf to be a body of intenſe fire; ſo this poreleſs homogeneous body, univerſally impregnated with luminous matter, without any acceſſion or pervaſion of the ſurrounding light, apparently becomes a compacted part thereof, and through its continuity and correſpondence of action, forms in reality, a part of the viſual beam, ſtanding in that direction between the ſun or object it comes from and the eye. For which reaſon philoſophers knowing the firmneſs of glaſs by the touch, and imagining that light flies off like grains of ſhot from the ſun, frame a notion of its pores, and ſuppoſe a real tranſition of light through diaphanous bodies.

But we are aſſured of the continuity of tranſparent bodies, as glaſs, diamond, &c. we alſo find that others only become tranſparent, when their pores are filled with fluid ſubſtances, which render theſe bodies in all parts homogeneous and continuous; for inſtance, paper with oil, air with the matter of light, the *oculus mundi* with water: beſides we know from the nature of light, that it is on its continuity and tenſion that inſtantaneous viſion depends; becauſe by this means any action at one end of the luminous beam that inſtant excites ſenſation at the other, by a protruſion of the whole elaſtic, continuous, and unyielding body of light that intervenes. From all which we know, that the tranſparent body, being continuous and of a luminous nature (from the quantity of that ſubſtance compacted and blended in it) is no ſooner immerſed in, or placed in contact with the flowing and vivid matter of the ſun or any other luminous body, than it is itſelf revived to the quality of a viſual agent, becomes capable of tranſmitting the ſenſation, and forms a part of that continuous beam, whoſe action on the eye produces viſion.

But on the other hand, when the body is compoſed of undigeſted heterogeneous matters, not elaborated to a ſtate of continuity, but in the groſs form of pores and particles;

here a continuation of the viſual beam is interrupted by the pores, for want of a continuity and tenſion of the luminous matter throughout the body; and conſequently its action is alſo interrupted, ſo that the vivid quality for want of a continuity of ſubſtance ceaſes and is reflected, as appears in the experiments before cited, for which reaſon ſuch bodies are not tranſparent, but opake. Now a body of this texture will be an obſtacle to the viſion of any body that impels light, whether by effuſion or reflection, whenever it is in a right line between ſuch luminous body and the eye; for the action of light is rectilineal and it has no power to change its direction from that of the impulſe, which one end of the beam receives from the body that urges it; therefore, when thus interrupted, a ſhadow ariſes behind the interceding body, which denotes its opacity. The protruding body, if luminous, acts upon the beam of light by the effuſion of new-born ſpecies; but, if opake, or reflective, it urges the viſual beam only by a reaction, which ariſes therein by the action of light, which preſſes againſt it: and this preſſure ariſes in the matter of light by the flowing motion it receives from the effuſing body.

Now, ſince the whole ſpherical ſpace illuminated by the ſun is replete with a continuous body of light ever flowing thus *in orbem*, and ever retaining its proper degree of tenſion, vivacity and intenſity, according to the diſtance of its ſpecies, from the ſource of its generation and action, any body immerſed therein will be acted upon by the force of theſe powers; and if the immerſed body be in ſubſtance a continuum, when ſo excited and illuminated, it ſhall apparently tranſmit the light and be tranſpicuous, as if it were a compacted part of the luminous effuſions, wherein it is immerſed. But if the immerſed body be porous and heterogeneous, it will abſorb or reflect it, ſo as to cauſe a ſhadow on one ſide and ſuch a reaction to the motion of light on every other ſide as will induce a preſſure that affects the eye, though not ſo ſenſibly as the forcible protruſion ariſing from the direct effuſions of a luminous body. Thus then the flowing luminous matter which has entered our atmoſphere is reflected to us from all parts thereof preſent to the ſun; and its vivacity is held up by the action and tenſion of the emanating ſpecies, ſo that all that part of the atmoſphere thus admitting and reflecting light, muſt be ſenſible to every eye opened in that hemiſphere, as long as the continuity of this luminous ſubſtance remains uninterrupted. This continuity, as was obſerved, is only interrupted by groſs porous and heterogeneous bodies, which, as before explained, are unfit to continue the tenſion and action of the light, which comes upon them, both on account of their inſufficiency of luminous matter, and of their pores which relax the viſual beam, and induce a *yielding*, whereby the continuous preſſure is interrupted. But although ſuch bodies, for the reaſons aſſigned, are not tranſpicuous, yet they are conſpicuous on account of the reaction above explained. And ſince the conſpicuouſneſs of all bodies is as the quantities of light they effuſe or reflect, and the action of light on every body is according to its intenſity and direction, when in contact therewith; it follows, that a diaphanous body ſhould equal in brilliancy or ſtrength, the light in contact with it, whether it be day-light or twilight, moon or ſtar-light; the light in water or in the atmoſphere, or that of a candle or of a glow-worm, &c. all which we experience by looking through glaſs during any of thoſe lights.

He that will ſtill maintain the porous tranſmiſſion, ſhould now point out how all this can be effected by pores: or rather firſt, on what pretence pores can be attributed to glaſs, in which no experiment or contrivance has yet diſcovered any: and if this means of tranſmiſſion were granted, he would ſtill have to explain how the twilight, ſtar-light, or that of a glow-worm gain ſuch force and propenſity as to effect a paſſage through glaſs to the eye, and how the opake bodies which are ſeen by theſe lights, are made viſible through glaſs. This is inexplicable by any other means, except by the revival of the ſubſtance of the ſame nature contextured in the glaſs or tranſparent body, which is excited to illumination, as the ignious concrete in bodies, is excited to heat from the fire, in which it lies, or with which it is placed in contact. And as this heat will be of the ſame degree of that wherein it lies, ſo will the light of a tranſparent body be excited to the degree of the ambient light. And as the metal bar communicates at one end the heat it has conceived at the other, without a tranſition of the fire through it, ſo the tranſparent body propagates the action of light, without any pervaſion of that ſubſtance through it. As to the ſlow progreſs of heat, it is a ſubject diſtinct from the preſent.

Many other unſurmountable difficulties ſhould alſo be ſolved by the abettors of the ſame opinion; as, for inſtance, how particles are ſhot from the ſtars through our atmoſphere, through water, and through glaſs; for they are viſible through theſe mediums? Then how the pores of theſe three bodies, the one firm, the others fluid, are brought into right lines? Thirdly, how the pores of the eye, which ſees thoſe objects through all theſe tranſparent bodies, fall again into the direction of the forementioned pores, without any contrivance of the obſerver; for the pupil is not an aperture? This lucky correſpondence of pores and particles to produce viſion, is only to be equalled by the good fortune of Epicurus's atoms in jumbling out the univerſe.

END OF THE FIRST PART.